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PERSHING PII INERTIAL MEASUREMENT UNIT CALIBRATION TREND STUDY.(U)
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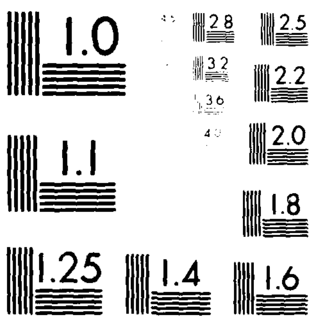

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TECHNICAL REPORT RG-80-20

PERSHING PII INERTIAL MEASUREMENT UNIT CALIBRATION TREND STUDY

H. V. White
Guidance and Control Directorate
US Army Missile Laboratory

March 1980

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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This report presents an overview of calibration data taken from Advanced Development Program Inertial Measurement Units. Behavior of calibration parameters is examined and worst/best performers are identified. Time trends are investigated by the method of linear least squares regression. Continued surveillance of parameters, determination of the effects of ill-behaved parameters on alignment and flight performance, and minimization of time required to perform a calibration are tasks to be performed during the Engineering Development program.

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FORWARD

The calibration data compiled and analyzed in this report were taken from Advanced Development (AD) Program Inertial Measurement Units (IMU) during the March 1976 to October 1978 time frame. Since that time some requirements and specifications given in the body of the report and various tables and charts have been changed for the Engineering Development (ED) Program based on findings during AD and pre-ED work. The criteria and discussions used in this report are those relative to AD.

During the pre-ED time period three IMUs (serial numbers 007, 011, and 012) were re-worked to incorporate many of the improvements identified during AD. As anticipated the resulting calibration parameter behavior is much improved. A future report will document the changes and analyze the performance of the modified units.

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I. INTRODUCTION AND OBJECT

The Pershing PII Inertial Measurement Unit (IMU) is a four gimbal, all attitude system incorporating two two-degree-of-freedom dry tuned gyros, one dual axis and one single axis force rebalance accelerometer.

IMU performance is largely dependent on gyro and accelerometer parameters which must either exhibit a high degree of absolute accuracy over the usable life of the IMU, or which must be amenable to a periodic calibration.

The PII IMU is a calibrated system and as such absolute accuracy of gyro and accelerometer parameters is unimportant. Instrument channel errors are measured in the calibration procedure and are software compensated so that a high degree of parameter stability is required rather than absolute accuracy.

A significant advantage of a calibrated system is cost savings resulting from relaxation of the requirements to design, fabricate and test for high absolute accuracy at both the component and system level. Instead, nominal parameter values are built in and are subsequently determined very accurately via the calibration procedure, allowing software compensation to be applied during ground alignment and flight modes. Frequency of calibration is determined by the stability of the measured parameters. Some of the advantage of a calibrated system is therefore lost if stability is such that frequent and lengthy calibrations are required.

The object of this study is to compile calibration data from all Engineering Model (EM) and Prototype Model (PM) IMUs for:

(1) Identification of least/most stable parameters

(2) Application of acceptance criteria to all runs

(3) Identification of data trends which may be useful to predict the time interval between calibrations.

The above information should be helpful in determining if the currently proposed calibration frequency of once per six months is realistic or if the time interval should be increased or decreased. The data should provide visibility of parameters which dictate a minimum time between calibrations. Application of acceptance criteria to all

calibration results should yield further insight into parameter behavior and overall system performance. An analysis of data trends should also aid in corroborating parameter stability and time between calibrations.

II. DISCUSSION OF CALIBRATION PROCEDURE AND OUTPUT DATA

Calibration of the PII IMU is an automatic procedure[1] performed under computer control. The instrument cluster (azimuth gimbal) is torqued to various positions to orient accelerometers relative to earth's g field and to orient gyros relative to earth's rotational field. Data, in the form of accelerometer and gyro torquing pulses, are acquired in a total of 13 positions. These data are utilized to compute 34 gyro and accelerometer parameters which are stored in the IMU Serial Core Memory (SCM) for later use in the ground alignment and flight modes. Currently, approximately 4 1/2 hours are required to perform a calibration.

The 34 calibrated parameters are shown in Table 1 along with definitions and units. Parameters with the letter H as a suffix are used in the ground alignment (gyrocompass) mode only. DELTA YX, DELTA ZY and DELTA ZX are factory/depot calibrated parameters and are measured in subsequent calibrations for goodness checks only. These three parameters along with two other factory/depot determined parameters, HSX and HSY, are stored in a protected portion of the SCM and theoretically are never updated except at the factory/depot. HSX and HSY are required for accurate gyrocompassing and are determined by a special purpose factory/depot test apart from the standard calibration procedure. Factory/depot determination of more accurate values of KIXH and KIYH for gyrocompass purposes has been proposed. This also requires a special purpose factory/depot test. The resulting values would be stored in the protected portion of the SCM and would be updated only at the factory/depot.

A measure of parameter stability is obtained by taking the difference between the value obtained from a new calibration and the value obtained from the original reference calibration. The 34 parameter differences are defined by adding the letter E as a suffix to each of the measured parameters, e.g., DFZE = DFZ (NEW) - DFZ (REF). Table 2 shows the proposed one sigma limits placed on each

1. The Singer Company, Kearfott Division; Document Y256A337, "Alignment Gyrocompass and IMU Parameter Compensation."

parameter difference. The specification requires that the IMU meet performance criteria with a calibration frequency of once every six months. It is therefore of prime importance that parameters remain stable over this interval of time as a minimum.

The acceptance test criteria utilized during the Advanced Development (AD) program allowed some degradation of the limits indicated in Table 2. For acceptance, all parameter values were required to lie within ± 3 sigma limits. If one or more of the flight parameters exceeded ± 1 sigma but did not lie outside ± 3 sigma, the Root Mean Square (RMS) value of all flight parameters, each normalized to its one sigma value, could not exceed a value of 1.3 for acceptance. Some flight parameters could therefore exceed the ± 1 sigma limits as could all of the ground alignment parameters but in no case was a value greater than ± 3 sigma acceptable.

III. DISCUSSION OF RESULTS

Calibration data considered in this study were taken from a total of 13 IMUs (4 EMs and 9 PMs) over a period of 30 months. Calibration sites were the Guidance and Control Directorate, Redstone Arsenal, Alabama and Martin Marietta Corporation, Orlando, Florida. The reference calibration was ordinarily performed at the Singer Company, Kearfott Division, Little Falls, New Jersey, however, some units required re-referencing at the other sites, usually due to electronic card replacement.

Table 3 gives a tabulation of number of calibrations and time frames involved for each IMU.

IMUs with serial numbers 001 through 004 are EMs and the remainder are PMs. Listing of an IMU more than once indicates that more than one reference calibration was utilized.

Several of the IMUs as indicated in Table 3, had very few calibrations performed, particularly those that were expended in AD flights. Only those units with six or more calibrations over a period of six or more months were subjected to the trend analysis presented in the appendix. Otherwise, a total of 117 calibration runs, which comprises the majority of runs made at Redstone and Martin, were considered for this study.

Results from the 10 calibration runs made with IMU serial number 005 during 11.4 months period are presented in Table 4, as a data sample. The data have been normalized by dividing the measured values of a given parameter by the allowable one sigma value given in Table 2.

Table 5 shows the number of times parameter differences fell in the indicated sigma ranges for each IMU. For example, the DFZE parameter from IMU serial number 001 was within the prescribed ± 1 sigma limits 18 out of the 26 calibrations. The parameter fell between ± 1 and ± 2 sigma four times and between ± 2 and ± 3 sigma four times. None of IMU serial 001 calibration runs yielded a DFZE greater than ± 3 sigma.

Percentage of calibration runs falling in the various sigma ranges for each parameter for all IMUs is shown in the last row of Table 5. A study of this table on an IMU basis over all parameters or on a parameter basis over all IMUs gives the indication that certain gyro parameters exhibit the least stability whereas certain accelerometer parameters are the most stable. These parameters are displayed in Figures 1, 2, and 3 which are derived from Table 5.

Figure 1 depicts the percentage of parameters from all calibrations which fell into the 0 ± 1 sigma range. Parameters in the left-most columns of Figure 1 are the least stable with DIXE and DIYE occurring in the 0 ± 1 sigma range for only 43 percent of the total of 117 measurements for each.

The range is expanded to 0 ± 2 sigma in Figure 2 which displays the same 12 parameters in the two left-most columns as are indicated in the three left-most columns of Figure 1.

Figure 3, in which the range is increased to 0 ± 3 sigma, indicates that six (left-most column) of the 12 parameters identified in Figures 1 and 2 are the very worst performers. The six are all gyro parameters, the definitions and units of which are given in Table 2.

The most stable parameters are the nine appearing in the right-most column of Figure 1. They are all accelerometer parameters. Definitions and units for these are given in Table 2 also.

Placement of the parameters in the vertical order shown in Figures 1 through 3 has no significance.

Data in Table 5 are further condensed in Table 6 which provides a summary of frequency of occurrence of difference parameters within the indicated sigma ranges for all IMUs and all calibrations. All parameters from all IMUs fall within the prescribed one sigma limits for only 75 percent of the total number of data points, however, 91 percent lie within 0±2 sigma bounds and 96 percent lie within 0±3 sigma bounds.

Table 7 presents results of the application of AD acceptance test criteria to all 117 calibration runs considered in this study. Fifty-five of 117 runs or 47.0 percent passed acceptance criteria, whereas 11 runs or 9.4 percent failed all criteria. One or more flight parameters greater than ±3 sigma in combination with larger than acceptable flight parameter RMS values, accounted for the highest combination failure category of 24 runs or 20.5 percent.

Table 8 lists RMS values of the 20 flight parameters for each calibration of each IMU. Sixty-five of 117 runs or 55.6 percent passed the RMS criterion of 1.3 sigma. The remaining runs, with one exception, yielded one or more parameters greater than ±3 sigma and thus failed. The single exception is run Number 9 from serial number 001 which failed to meet the RMS criterion of 1.3 sigma even though no parameter greater than ±3 sigma was measured. Thirteen runs or 11.1 percent met the RMS criteria even though one or more parameters were greater than ±3 sigma.

IV. CONCLUSIONS AND RECOMMENDATIONS

This study has taken the initial overview of the majority of calibration data from all AD IMUs.

Identification of parameters which most often exceeded three sigma limits has been accomplished. These are DFX, DIX, DIY, DIZ, KTX and KTZ which are all gyro parameters . Most stable parameters are KIZH, KOY, KOZ, KOXH, KOYH, KOZH, DELTA YX, DELTA ZX and DELTA ZY which are associated with the accelerometers.

Application of AD acceptance criteria to all runs shows that only 47.0 percent passed the three sigma criterion and 55.6 percent passed the 1.3 sigma flight criterion.

The Appendix addresses the question of trends by using the linear least squares regression method. The three sigma criterion was used to establish a predicted worst case time between calibrations and in very few cases is this time less than the AD program required time of six months. However, many of the parameters would fail the six months time criterion when one sigma limits are imposed.

The plotted data in the Appendix and the corresponding tables give some visibility on trending parameters. Parameters with correlation coefficients near unity are trending suspects. Gyro parameters KTX, KTY and KTZ and accelerometer parameters KIX, KIXH, KIY and KIYH show the greatest propensity toward trending. Conversely, those parameters with correlation coefficients near zero are more random in nature.

The general conclusion is that many of the parameters need to be better behaved. There appears to be some problem associated with test locations as indicated by the plotted data in the Appendix from IMU serial number 005, i.e., note data points taken at Martin (M) compared to those taken at the Guidance and Control Directorate (A).

It is recommended that close surveillance of the calibration parameters be continued into the Engineering Development (ED) program as component and system improvements are incorporated. Those parameters which are not well behaved should be reviewed for their effects on alignment and flight accuracy, and methods for improving performance should be defined and implemented.

A factor which requires further investigation is minimization of time required for performing calibration. The current routine has not been time-optimized for field usage. Elimination of certain parameters required only in a factory calibration and optimizing the sequence of positions to avoid backtracking between positions are two possibilities for decreasing time.

Additionally, evaluation of the calibration operation under field-type conditions will be necessary to determine the impact of environmental factors and unknown initial heading on calibration time.

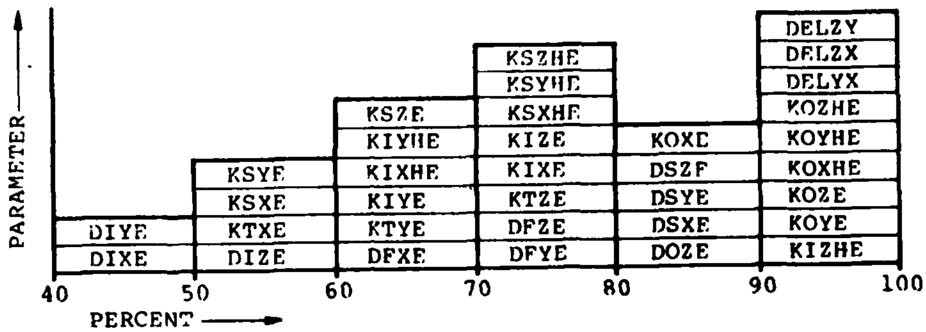

Figure 1. Percent of parameters in the 0 ± 1 sigma range.

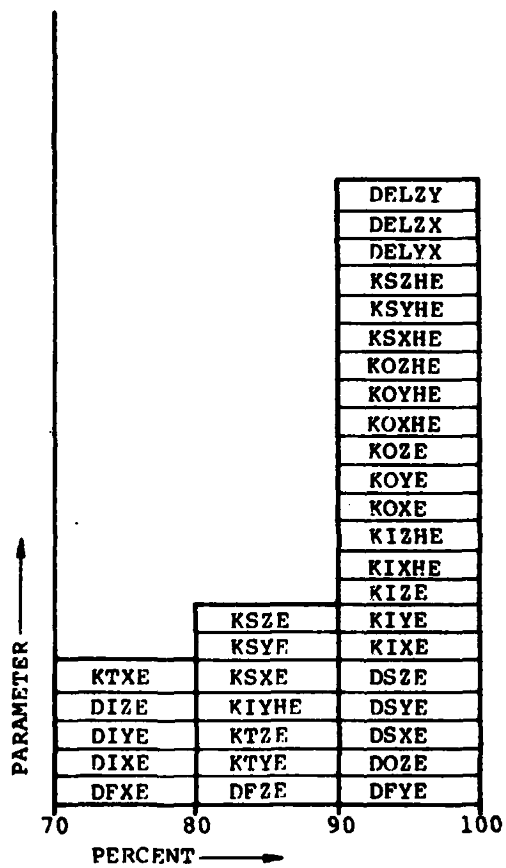

Figure 2. Percent of parameters in the 0 ± 2 sigma range.

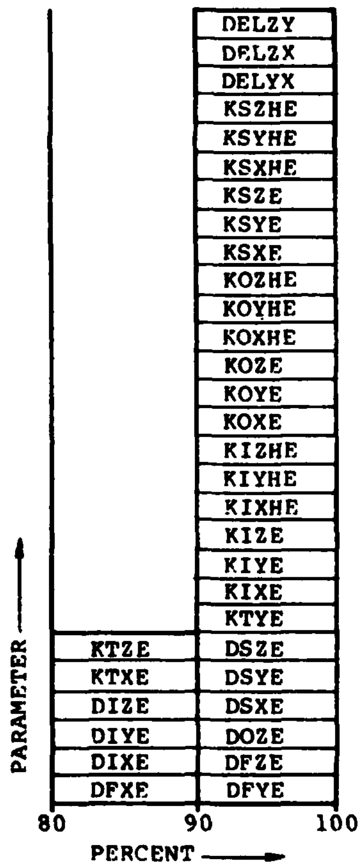

Figure 3. Percent of parameters in the 0 ± 3 sigma range.

TABLE 1. CALIBRATED PARAMETERS

Parameter	
KTX	X Gyro Torquer Scale Factor (deg/hr per deg/hr)
KTY	Y Gyro Torquer Scale Factor (deg/hr per deg/hr)
KTZ	Z Gyro Torquer Scale Factor (deg/hr per deg/hr)
DFZ	Fixed Drift of Z Gyro (deg/hr)
DSZ	G Sensitive Drift of Z Gyro (Spin Axis) (deg/hr per ft/sec^2)
DIZ	G Sensitive Drift of Z Gyro (Input Axis) (deg/hr per ft/sec^2)
KIY	Y Accelerometer Scale Factor (Flight) (μg/g)
KIYH	Y Accelerometer Scale Factor (Ground) (μg/g)
KIX	X Accelerometer Scale Factor (Flight) (μg/g)
KIXH	X Accelerometer Scale Factor (Ground) (μg/g)
DOZ	G Sensitive Drift of Z Gyro (Output Axis) (deg/hr per ft/sec^2)
DFX	Fixed Drift of X Gyro (deg/hr)
KIZ	Z Accelerometer Scale Factor (Flight) (μg/g)
KIZH	Z Accelerometer Scale Factor (Ground) (μg/g)
DFY	Fixed Drift of Y Gyro (deg/hr)
DSX	G Sensitive Drift of X Gyro (Spin Axis) (deg/hr per ft/sec^2)
DSY	G Sensitive Drift of Y Gyro (Spin Axis) (deg/hr per ft/sec^2)
DIX	G Sensitive Drift of X Gyro (Input Axis) (deg/hr per ft/sec^2)
DIY	G Sensitive Drift of Y Gyro (Input Axis) (deg/hr per ft/sec^2)
DELTA YX	Non-Orthogonality Between Y & X Accelerometers (rad)
DELTA ZY	Non-Orthogonality Between Z & X Accelerometers (rad)
KOZ	Z Accelerometer Bias (Flight) (ft/sec^2)
KSZ	Z Accelerometer Scale Factor Asymmetry (Flight) (μg/g)
KOZH	Z Accelerometer Bias (Ground) (ft/sec^2)
KSZH	Z Accelerometer Scale Factor Asymmetry (Ground) (μg/g)
KOX	X Accelerometer Bias (Flight) (ft/sec^2)
KSX	X Accelerometer Scale Factor Asymmetry (Flight) (μg/g)
KOXH	X Accelerometer Bias (Ground) (ft/sec^2)
KSXH	X Accelerometer Scale Factor Asymmetry (Ground) (μg/g)

TABLE 1. (Concluded)

Parameter	
DELTA ZX	Non-Orthogonality Between Z & Y Accelerometers (rad)
KOY	Y Accelerometer Bias (Flight) (ft/sec^2)
KSY	Y Accelerometer Scale Factor Asymmetry (Flight) ($\mu g/g$)
KOYH	Y Accelerometer Bias (Ground) (ft/sec^2)
KSYH	Y Accelerometer Scale Factor Asymmetry (Ground) ($\mu g/g$)

TABLE 2. DIFFERENCE PARAMETER LIMITS

Difference Parameter	$\pm 1\sigma$ Max Criteria	$\pm 3\sigma$ Max Criteria
DFZE	.025°/hr	.075°/hr
DSZE	.025°/hr/g	.075°/hr/g
DIZE	.03°/hr/g	.09°/hr/g
KIYE	100 μg/g	300 μg/g
KIYHE	100 μg/g	300 μg/g
KIXE	100 μg/g	300 μg/g
KIXHE	100 μg/g	300 μg/g
DOZE	.02°/hr/g	.06°/hr/g
DFXE	.025°/hr	.075°/hr
KIZE	100 μg/g	300 μg/g
KIZHE	100 μg/g	300 μg/g
DFYE	.025°/hr	.075°/hr
DSXE	.025°/hr/g	.075°/hr/g
DSYE	.025°/hr/g	.075°/hr/g
DIXE	.03°/hr/g	.09°/hr/g
DIYE	.03°/hr/g	.09°/hr/g
DELTYX	.00008 rad	.00025 rad
DELTZY	.00020 rad	.00060 rad
KOZE	300 μg	900 μg
KSZE	50 μg/g	150 μg/g
KOZHE	300 μg	900 μg
KSZHE	50 μg/g	150 μg/g
KOXE	100 μg	300 μg
KSXE	50 μg/g	150 μg/g
KOXHE	100 μg	300 μg
KSXHE	50 μg/g	150 μg/g
DELTZX	.00015 rad	.00045 rad
KOYE	100 μg	300 μg
KSYE	50 μg/g	150 μg/g
KOYHE	100 μg	300 μg
KSYHE	50 μg/g	150 μg/g
KTXE	.0002°/hr per °/hr	.0006°/hr per °/hr
KTYE	.0002°/hr per °/hr	.0006°/hr per °/hr
KTZE	.0002°/hr per °/hr	.0006°/hr per °/hr

TABLE 3. NUMBER OF IMU CALIBRATIONS AND TIME FRAMES

IMU S/N	NO. CAL.	NO. MONTHS	TIME FRAME	REMARKS
001	26	13.6	3/76 - 5/77	
002	9	3.0	2/76 - 5/76	
002	18	7.1	5/76 - 12/76	
003	6	1.9	9/76 - 11/76	
003	9	6.4	1/77 - 7/77	
004	7	5.0	9/76 - 2/77	
005	10	11.4	6/77 - 6/78	
006	3	4.8	5/77 - 10/78	
006	4	3.0	12/77 - 3/78	AD FLT 4
007	5	8.7	6/77 - 3/78	
008	3	5.3	6/77 - 11/77	AD FLT 2
009	1	1.4	9/77 - 11/77	AD FLT 3
010	1	1.6	8/77 - 9/77	AD FLT 1
011	2	3.8	7/77 - 11/77	
012	1	6.5	8/77 - 2/78	
012	5	3.7	4/78 - 8/78	
013	7	2.5	2/78 - 5/78	AD FLT 5
TOTALS	117	89.7		

TABLE 4. I
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DATE	LOCATION	ELAPSED TIME (MONTHS)	DFZE	DSZE	DIZE	KIYE
06/28/77	SKD	0 (REF)				
08/05/77	MMC	1.27	-.81	1.93	-.73	-.35
11/08/77	RSA	4.43	.58	1.56	-1.53	-.58
11/29/77	RSA	5.13	.50	1.48	-.30	-.45
12/07/77	RSA	5.40	-.11	1.78	-1.03	-.43
12/16/77	RSA	5.70	0	1.63	-2.43	-.83
01/03/78	RSA	6.30	.81	1.38	-.56	-1.42
01/11/78	MMC	6.56	-.24	1.62	-1.45	-1.10
02/27/78	MMC	8.13	.11	1.28	-1.51	-1.55
03/23/78	MMC	8.93	-.02	1.23	-1.19	-1.45
06/06/78	MMC	11.43	1.50	2.70	-9.70	-1.80

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TABLE 4. IMU S/N 005 NORMALIZED DATA
REFERENCE CALIBRATION:
JUNE 28, 1977

[illegible]	DIZE	KIYE	KIYHE	KIXE	KIXHE	DOZE	DFXE	KIZE	KIZHE	DFYE	DSXE	DSYE
3	-.73	-.35	-.54	-.06	-.38	-.70	.08	-.12	.22	-.58	.16	-.16
6	-1.53	-.58	-1.10	-.73	-1.28	-1.00	-.40	-1.14	.69	-.74	-.36	.36
8	-.30	-.45	-.87	-.56	-1.06	-.50	-.40	1.08	.64	.32	-.44	.44
8	-1.03	-.43	-.78	-.14	-1.02	-.20	-.79	1.12	.64	.39	-.48	.48
3	-2.43	-.83	-1.15	-.65	-1.31	.20	-.56	.76	.39	-.07	-.48	.48
8	-.56	-1.42	-1.84	-1.51	-2.02	-1.60	-.38	.65	.29	.63	-.36	.36
2	-1.45	-1.10	-2.24	-.78	1.55	-.45	-.36	-.46	-.72	.10	.12	-.12
8	-1.51	-1.55	-1.86	-1.28	-1.72	.02	-.72	-.36	-.55	1.14	-.28	.28
3	-1.19	-1.45	-2.70	-1.18	1.12	1.12	-.74	-.37	-.62	1.56	-.36	.36
0	-9.70	-1.80	-3.00	-1.80	.80	.56	-.09	-.36	-.56	1.80	.15	-.15

TABLE 4.

DATE	LOCATION	ELAPSED TIME (MONTHS)	DIXE	DIYE	ΔYX	ΔYZ	KOZE
06/28/77	SKD	0 (REF)					
08/05/77	MMC	1.27	.10	.10	.07	.01	-.3[illegible]
11/08/77	RSA	4.43	-4.13	-4.13	.84	.03	-.6[illegible]
11/29/77	RSA	5.13	-1.70	-1.70	1.16	0	-.0[illegible]
12/07/77	RSA	5.40	-4.60	-4.60	.68	.01	-.1[illegible]
12/16/77	RSA	5.70	2.80	2.80	1.20	0	-.0[illegible]
01/03/78	RSA	6.30	-2.67	-2.67	.14	.02	-.0[illegible]
01/11/78	MMC	6.56	-.07	-.07	.05	0	-.[illegible]
02/27/78	MMC	8.13	-.06	-.06	.10	.02	-.[illegible]
03/23/78	MMC	8.93	-1.37	-1.37	.34	.03	-.[illegible]
06/06/78	MMC	11.43	-1.04	-1.04	.29	.28	-.[illegible]

TABLE 4. (Continued)

ΔYZ	KOZE	KSZE	KOZHE	KSZHE	KOXE	KSXE	KOXHE	KSXHE	ΔZX	KOYE
.01	-.31	-1.47	-.09	.11	-.34	-.60	-.06	.14	.41	.56
.03	-.60	-1.92	-.25	.69	-1.45	-3.64	-.26	-.72	.54	.65
0	-.07	.80	-.26	.16	-.08	-.42	-.30	-.63	1.36	-.62
.01	-.19	.29	-.19	.33	.28	.09	-.21	-.59	1.19	-.47
0	-.06	.22	-.15	.03	-.10	-.11	-.17	-.57	1.20	-.57
.02	-.06	.79	-.23	.15	-.01	-.32	-.35	-1.08	1.24	-.35
0	-.32	-1.13	-.21	-.23	-.77	-1.72	.02	-.02	.61	.70
.02	-.19	.21	-.28	-.04	-.61	-1.07	.01	-.33	.68	.64
.03	-.20	.59	-.36	-.15	-.88	-1.75	-.08	-.19	.66	.56
.28	-.60	-.60	-.50	.12	-.60	-1.30	-.14	-.34	.70	.40

TABLE 4. (Concluded)

DATE	LOCATION	ELAPSED TIME (MONTHS)	KSYE	KOYHE	KSYHE
06/28/77	SKD	0 (REF)			
08/05/77	MMC	1.27	1.20	-.10	.26
11/08/77	RSA	4.43	1.27	-.09	.22
11/29/77	RSA	5.13	-.91	.16	.71
12/07/77	RSA	5.40	-.94	.15	.52
12/16/77	RSA	5.70	-1.09	-.04	.11
01/03/78	RSA	6.30	-.45	-.18	.22
01/11/78	MMC	6.56	1.71	-.05	.08
02/27/78	MMC	8.13	1.00	.10	-.03
03/23/78	MMC	8.93	1.09	.08	.03
06/06/78	MMC	11.43	1.05	.11	.39

TABLE 4. (Concluded)

APSED IME NTHS)	KSYE	KOYHE	KSYHE	KTXE	KTYE	KTZE
(REF)						
.27	1.20	-.10	.26	-.70	-.46	1.07
.43	1.27	-.09	.22	-.58	.44	2.52
.13	-.91	.16	.71	-.34	-.74	1.95
.40	-.94	.15	.52	.53	.10	2.68
.70	-1.09	-.04	.11	.92	-.65	2.30
.30	-.45	-.18	.22	1.04	4.19	3.10
.56	1.71	-.05	.08	.16	-.34	2.86
.13	1.00	.10	-.03	1.80	-.10	3.10
.93	1.09	.08	.03	1.94	.06	3.42
.43	1.05	.11	.39	1.80	.31	3.10

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TABLE 5. IMU CALIBRATION DATA - PARAMETER RANGE (INDI
ENTRIES ARE FREQUENCY OF OCCURRENCE

IMU S/N	DFZE SIGMA RANGE				DSZE SIGMA RANGE				DIZE SIGMA RANGE				KIYE SIGMA RANGE				K SIGM	
	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2
001	18	4	4	0	21	4	1	0	4	5	8	9	20	6	0	0	23	3
002	20	6	0	0	27	0	0	0	18	6	2	1	16	11	0	0	14	8
003	13	2	0	0	15	0	0	0	13	2	0	0	13	2	0	0	13	2
004	7	0	0	0	7	0	0	0	6	0	0	1	7	0	0	0	6	1
005	9	1	0	0	0	9	1	0	3	5	1	1	5	5	0	0	3	4
006	3	1	2	1	5	2	0	0	4	1	1	1	6	1	0	0	4	2
007	1	4	0	0	5	0	0	0	0	0	0	5	5	0	0	0	5	0
008	3	0	0	0	3	0	0	0	3	0	0	0	1	2	0	0	0	1
009	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0
010	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1
011	1	1	0	0	2	0	0	0	2	0	0	0	0	2	0	0	0	1
012	[illegible]	0	0	5	5	1	0	0	3	0	1	2	5	1	0	0	5	1
013	5	1	1	0	7	0	0	0	6	0	0	1	1	6	0	0	1	5
TOTALS	83	20	7	6	99	16	2	0	64	19	13	21	81	36	0	0	74	29
%	72	17	6	5	85	14	1	0	55	16	11	18	69	31	0	0	63	25

RATION DATA - PARAMETER RANGE (INDIVIDUAL IMUs)
ARE FREQUENCY OF OCCURRENCE

DIZE SIGMA RANGE			KIYE SIGMA RANGE				KIYHE SIGMA RANGE				KIXE SIGMA RANGE				KIXHE SIGMA RANGE			
±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3
5	8	9	20	6	0	0	23	3	0	0	19	7	0	0	24	2	0	0
6	2	1	16	11	0	0	14	8	5	0	27	0	0	0	15	12	0	0
2	0	0	13	2	0	0	13	2	0	0	7	8	0	0	8	7	0	0
0	0	1	7	0	0	0	6	1	0	0	4	3	0	0	7	0	0	0
5	1	1	5	5	0	0	3	4	2	1	6	4	0	0	2	7	1	0
1	1	1	6	1	0	0	4	2	0	1	5	2	0	0	4	2	0	1
0	0	5	5	0	0	0	5	0	0	0	5	0	0	0	4	1	0	0
0	0	0	1	2	0	0	0	1	2	0	0	0	3	0	0	0	3	0
0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0
0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0
0	0	0	0	2	0	0	0	1	0	1	1	1	0	0	0	1	0	1
0	1	2	5	1	0	0	5	1	0	0	5	1	0	0	5	1	0	0
0	0	1	1	6	0	0	1	5	1	0	1	6	0	0	1	6	0	0
9	13	21	81	36	0	0	74	29	11	3	82	32	3	0	70	41	4	2
6	11	18	69	31	0	0	63	25	9	3	70	27	3	0	60	35	3	2

TABLE 5. (Continued)

IMU S/N	DOZE SIGMA RANGE				DFXE SIGMA RANGE				KIZE SIGMA RANGE				KIZHE SIGMA RANGE				
	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1
001	22	3	0	1	10	5	2	9	25	1	0	0	22	2	2	0	19
002	25	2	0	0	27	0	0	0	11	11	2	3	27	0	0	0	27
003	15	0	0	0	7	1	4	3	14	1	0	0	14	0	1	0	8
004	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0	4
005	8	2	0	0	10	0	0	0	7	3	0	0	10	0	0	0	7
006	3	3	1	0	7	0	0	0	4	2	1	0	7	0	0	0	7
007	5	0	0	0	0	2	1	2	5	0	0	0	1	2	0	2	1
008	2	1	0	0	1	0	2	0	3	0	0	0	3	0	0	0	3
009	0	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1
010	0	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1
011	2	0	0	0	0	0	1	1	2	0	0	0	2	0	0	0	0
012	6	0	0	0	6	0	0	0	5	1	0	0	4	2	0	0	6
013	6	1	0	0	2	3	2	0	2	2	3	0	7	0	0	0	7
TOTALS	101	14	1	1	79	11	12	15	87	21	6	3	106	6	3	2	91
%	86	12	1	1	68	9	10	13	74	18	5	3	90	5	3	2	78

TABLE 5. (Continued)

KIZE SIGMA RANGE				KIZHE SIGMA RANGE				DFYE SIGMA RANGE				DSXE SIGMA RANGE				DSYE SIGMA RANGE			
±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3
25	1	0	0	22	2	2	0	19	6	1	0	25	0	0	1	25	0	0	1
11	11	2	3	27	0	0	0	27	0	0	0	26	1	0	0	26	1	0	0
14	1	0	0	14	0	1	0	8	4	3	0	9	5	0	1	9	5	0	1
7	0	0	0	7	0	0	0	4	3	0	0	7	0	0	0	7	0	0	0
7	3	0	0	10	0	0	0	7	3	0	0	10	0	0	0	10	0	0	0
4	2	1	0	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0
5	0	0	0	1	2	0	2	1	0	1	3	1	3	0	1	1	3	0	1
3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
2	0	0	0	2	0	0	0	0	0	0	2	2	0	0	0	2	0	0	0
5	1	0	0	4	2	0	0	6	0	0	0	5	1	0	0	5	1	0	0
2	2	3	0	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0
87	21	6	3	106	6	3	2	91	16	5	5	104	10	0	3	104	10	0	3
74	18	5	3	90	5	3	2	78	14	4	4	89	8	0	3	89	8	0	3

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TABLE 5. (Continued)

IMU S/N	DIXE SIGMA RANGE				DIYE SIGMA RANGE				DELTYX SIGMA RANGE				DELTZY SIGMA RANGE				SIG	
	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2
001	10	7	8	1	10	7	8	1	23	3	0	0	26	0	0	0	26	0
002	17	5	3	2	17	5	3	2	27	0	0	0	27	0	0	0	27	0
003	4	10	1	0	4	10	1	0	13	2	0	0	15	0	0	0	14	1
004	2	0	1	4	2	0	1	4	5	2	0	0	7	0	0	0	7	0
005	3	3	2	2	3	3	2	2	8	2	0	0	10	0	0	0	10	0
006	2	1	0	4	2	1	0	4	7	0	0	0	7	0	0	0	7	0
007	0	4	0	1	0	4	0	1	5	0	0	0	5	0	0	0	5	0
008	0	1	0	2	0	1	0	2	2	1	0	0	3	0	0	0	1	2
009	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
010	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
011	2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0	2	0
012	5	0	1	0	5	0	1	0	6	0	0	0	5	1	0	0	6	0
013	3	3	1	0	3	3	1	0	7	0	0	0	7	0	0	0	7	0
TOTALS	50	34	17	16	50	34	17	16	107	10	0	0	116	1	0	0	114	3
%	43	29	14	14	43	29	14	14	91	9	0	0	99	1	0	0	97	3

TABLE 5. (Continued)

DELTYX SIGMA RANGE			DELTZY SIGMA RANGE				KOZE SIGMA RANGE				KSZE SIGMA RANGE				KOZHE SIGMA RANGE			
±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3
3	0	0	26	0	0	0	26	0	0	0	7	7	12	0	26	0	0	0
0	0	0	27	0	0	0	27	0	0	0	24	3	0	0	27	0	0	0
2	0	0	15	0	0	0	14	1	0	0	12	3	0	0	15	0	0	0
2	0	0	7	0	0	0	7	0	0	0	1	5	1	0	7	0	0	0
2	0	0	10	0	0	0	10	0	0	0	7	3	0	0	10	0	0	0
0	0	0	7	0	0	0	7	0	0	0	3	4	0	0	7	0	0	0
0	0	0	5	0	0	0	5	0	0	0	4	1	0	0	3	1	0	1
1	0	0	3	0	0	0	1	2	0	0	1	0	0	2	3	0	0	0
0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
0	0	0	2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0
0	0	0	5	1	0	0	6	0	0	0	5	1	0	0	6	0	0	0
0	0	0	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0
0	0	0	116	1	0	0	114	3	0	0	75	27	13	2	115	1	0	1
	0	0	99	1	0	0	97	3	0	0	64	23	11	2	98	1	0	1

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TABLE 5. (Continued)

IMU S/N	KSZHE SIGMA RANGE				KOXE SIGMA RANGE				KSXE SIGMA RANGE				KOXHE SIGMA RANGE				SIG	
	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±
001	10	12	4	0	24	2	0	0	17	7	2	0	26	0	0	0	17	
002	27	0	0	0	21	6	0	0	10	8	6	3	26	1	0	0	15	1
003	13	2	0	0	14	1	0	0	7	6	2	0	15	0	0	0	15	
004	6	1	0	0	5	2	0	0	3	2	2	0	6	1	0	0	3	
005	10	0	0	0	9	1	0	0	5	4	0	1	10	0	0	0	9	
006	6	1	0	0	3	4	0	0	7	0	0	0	6	1	0	0	4	
007	2	1	0	2	4	1	0	0	2	3	0	0	5	0	0	0	4	
008	2	1	0	0	3	0	0	0	2	1	0	0	3	0	0	0	2	
009	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	
010	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	
011	2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0	1	
012	6	0	0	0	5	0	1	0	2	3	1	0	5	0	1	0	6	
013	7	0	0	0	7	0	0	0	6	1	0	0	7	0	0	0	5	
TOTALS	93	18	4	2	99	17	1	0	63	36	14	4	113	3	1	0	83	3
%	79	15	3	2	85	14	1	0	54	31	12	3	96	3	1	0	71	2

TABLE 5. (Continued)

KSXE SIGMA RANGE				KOXHE SIGMA RANGE				KSXHE SIGMA RANGE				DELTZX SIGMA RANGE				KOYE SIGMA RANGE			
±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3	±1	±2	±3	> ±3
17	7	2	0	26	0	0	0	17	9	0	0	26	0	0	0	23	3	0	0
10	8	6	3	26	1	0	0	15	11	1	0	27	0	0	0	26	1	0	0
7	6	2	0	15	0	0	0	15	0	0	0	13	1	1	0	14	1	0	0
3	2	2	0	6	1	0	0	3	2	2	0	7	0	0	0	6	0	1	0
5	4	0	1	10	0	0	0	9	1	0	0	6	4	0	0	10	0	0	0
7	0	0	0	6	1	0	0	4	3	0	0	7	0	0	0	7	0	0	0
2	3	0	0	5	0	0	0	4	1	0	0	4	1	0	0	1	2	1	1
2	1	0	0	3	0	0	0	2	1	0	0	3	0	0	0	2	1	0	0
0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
0	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
2	0	0	0	2	0	0	0	1	1	0	0	2	0	0	0	2	0	0	0
2	3	1	0	5	0	1	0	6	0	0	0	6	0	0	0	5	1	0	0
6	1	0	0	7	0	0	0	5	2	0	0	7	0	0	0	7	0	0	0
63	36	14	4	113	3	1	0	83	31	3	0	110	6	1	0	105	9	2	1
54	31	12	3	96	3	1	0	71	26	3	0	94	5	1	0	90	8	2	1

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TABLE 5. (Concluded)

IMU S/N	KSYE SIGMA RANGE				KOYHE SIGMA RANGE				KSYHE SIGMA RANGE				KTXE SIGMA RA		
	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3
001	12	12	2	0	25	0	1	0	22	3	0	1	8	5	4
002	17	5	4	1	22	5	0	0	12	15	0	0	14	2	1
003	9	5	1	0	15	0	0	0	15	0	0	0	10	2	1
004	3	3	1	0	6	0	1	0	5	2	0	0	4	1	0
005	4	6	0	0	10	0	0	0	10	0	0	0	6	4	0
006	3	3	1	0	7	0	0	0	7	0	0	0	6	1	0
007	1	2	1	1	5	0	0	0	1	4	0	0	2	0	0
008	1	1	0	1	3	0	0	0	0	3	0	0	1	0	[illegible]
009	1	0	0	0	1	0	0	0	1	0	0	0	1	0	[illegible]
010	1	0	0	0	1	0	0	0	1	0	0	0	0	0	[illegible]
011	2	0	0	0	2	0	0	0	2	0	0	0	0	0	[illegible]
012	3	3	0	0	5	1	0	0	5	1	0	0	3	2	[illegible]
013	7	0	0	0	7	0	0	0	5	2	0	0	2	4	[illegible]
TOTALS	64	40	10	3	109	6	2	0	86	30	0	1	57	21	[illegible]
%	55	34	8	3	93	5	2	0	74	26	0	1	54	20	[illegible]

TABLE 5. (Concluded)

E ANGE	KSYHE SIGMA RANGE				KTXE SIGMA RANGE				KTYE SIGMA RANGE				KTZE SIGMA RANGE			
>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3	±1	±2	±3	>±3
0	22	3	0	1	8	5	4	3	6	9	4	1	19	1	0	0
0	12	15	0	0	14	2	1	7	20	3	1	0	17	0	1	6
0	15	0	0	0	10	2	1	1	12	0	2	0	14	0	0	0
0	5	2	0	0	4	1	0	0	4	1	0	0	5	0	0	0
0	10	0	0	0	6	4	0	0	9	0	0	1	0	2	4	4
0	7	0	0	0	6	1	0	0	4	3	0	0	5	2	0	0
0	1	4	0	0	2	0	0	3	1	1	0	3	4	1	0	0
0	0	3	0	0	1	0	2	0	0	0	3	0	2	0	1	0
0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0
0	2	0	0	0	0	0	0	2	0	0	0	2	0	0	1	1
0	5	1	0	0	3	2	0	1	3	0	1	2	3	2	0	1
0	5	2	0	0	2	4	1	0	5	2	0	0	2	2	2	1
0	86	30	0	1	57	21	9	18	65	19	11	10	73	10	9	13
0	74	26	0	1	54	20	9	17	62	18	10	10	70	10	9	12

TABLE 6. IMU CALIBRATION DATA - PARAMETER RANGE (ALL IMUs, ALL CALIBRATIONS) ENTRIES ARE FREQUENCY OF OCCURRENCE

PARAMETER	$\pm 1\sigma$	$\pm 2\sigma$	$\pm 3\sigma$	$>\pm 3\sigma$	
DFZE	83	20	7	6	
DSZE	99	16	2	0	
DIZE	64	19	13	21	
KIYE	81	36	0	0	
KIYHE	74	29	11	3	
KIXE	82	32	3	0	
KIXHE	70	41	4	2	
DOZE	101	14	1	1	
DFXE	79	11	12	15	
KIZE	87	21	6	3	
KIZHE	106	6	3	2	
DFYE	91	16	5	5	
DSXE	104	10	0	3	
DSYE	104	10	0	3	
DIXE	50	34	17	16	
DIYE	50	34	17	16	
DELYX	107	10	0	0	
DELZY	116	1	0	0	
KOZE	114	3	0	0	
KSZE	75	27	13	2	
KOZHE	115	1	0	1	
KSZHE	93	18	4	2	
KOXE	99	17	1	0	
KSXE	63	36	14	4	
KOXHE	113	3	1	0	
KSXHE	83	31	3	0	
DELZX	110	6	1	0	
KOYE	105	9	2	1	
KSYE	64	40	10	3	
KOYHE	109	6	2	0	
KSYHE	86	30	0	1	
KTXE	57	21	9	18	
KTYE	65	19	11	10	
KTZE	73	10	9	13	
TOTALS	2971	637	182	151	TOTAL 3941
%	75	16	5	4	

TABLE 7. IMU CALIBRATION DATA - AD ACCEPTANCE TEST CRITERIA APPLIED

S/N MOS	S/N 001 26 CALS 13.6 MOS	S/N 002 9 CALS 3.0 MOS	S/N 002 18 CALS 7.1 MOS	S/N 003 6 CALS 1.9 MOS	S/N 003 9 CALS 6.4 MOS	S/N 004 7 CALS 5.0 MOS	S/N 005 10 CALS 11.4 MOS	S/N 006 3 CALS 4.8 MOS	S/N 006 4 CALS 3.0 MOS	S/N 007 5 CALS 8.7 MOS	S/N 008 3 CALS 5.3 MOS	S/N 009 1 CAL 1.4 MOS	S/N 010 1 CAL 1.6 MOS	S/N 011 2 CALS 3.8 MOS	S/N 012 1 CAL 6.5 MOS	S/N 012 5 CALS 3.7 MOS	S/N 013 7 CALS 2.5 MOS
	p p p p p p	p o Δ Δ o o Δ	p p p p p p	p p p p Δ p	p p p p o o □	o o □ o p o □ p	p o □ p o p Δ	o □ o □ o □	Δ o □ p o	Δ o □ Δ o □ o □ Δ o □ Δ o □	p o □ o □	p	Δ	Δ o □ Δ o □	Δ o □	p o □ o □ o □ o □	o p p p p
	p p □ p p p	Δ o Δ o Δ	p p p p p p		p o □ o □	p	p p Δ o										p
	o □ Δ o □ o □ Δ o □ Δ o □ o □		p p p o o o						EXPENDED AD FLT 4		EXPENDED AD FLT 2	EXPENDED AD FLT 3	EXPENDED AD FLT 1				EXPENDED AD FLT 5
	o o □ o □ o □ p o □																
	Δ o □																

LEGEND
p = PASS
o = FLIGHT PARAMETER >3σ
□ = FLIGHT PARAMETER >1.3σ
Δ = NON-FLIGHT PARAMETER >3σ

P:	47%
o:	11%
Δ:	1%
□:	8%
o□:	20%
Δo:	2%
Δo□:	9%

TABLE 8. IMU CALIBRATION DATA - RMS OF 20 FLIGHT PARAMETERS

CAL NO.	S/N MOS	S/N 001 26 CALS 13.6 MOS	S/N 002 9 CALS 3.0 MOS	S/N 002 18 CALS 7.1 MOS	S/N 003 6 CALS 1.9 MOS	S/N 003 9 CALS 6.4 MOS	S/N 004 7 CALS 5.0 MOS	S/N 005 10 CALS 11.4 MOS	S/N 006 10 CALS 4.8 MOS	S/N 006 4 CALS 3.0 MOS	S/N 007 5 CALS 8.7 MOS	S/N 008 3 CALS 5.3 MOS	S/N 009 1 CAL 1.4 MOS	S/N 010 1 CAL 1.6 MOS	S/N 011 2 CALS 3.8 MOS	S/N 012 1 CAL 6.5 MOS	S/N 012 5 CALS 3.7 MOS	S/N 013 7 CALS 2.5 MOS
1		.96	1.02	.59	.46	.74	●1.16	.75	●1.66	.73	●3.16	1.04	.80	.61	●1.74	●11.92	.52	●.91
2		.93	●1.07	.42	.66	.69	●1.53	●1.60	●1.45	●1.32	●2.70	●1.64			●1.42		●2.53	.69
3		1.13	.95	.21	.81	.86	●1.07	.83	●1.76	.93	●3.03	●1.91					●2.54	.83
4		1.05	●1.15	.53	.79	.74	1.02	●1.28		●1.02	●3.35						●2.69	.79
5		.91	●1.16	.52	1.16	●1.09	●1.56	1.10			●4.54						●3.53	.90
6		1.00	.87	.56	1.14	●1.34	.84	1.04										1.10
7		.76	●1.10	.75		.50	1.04	.92										1.02
8		.83	●1.20	.54		●1.76		.84										
9		1.40	.76	.63		●2.30		1.00										
10		1.15		.86				●2.51										
11		1.14		.84														
12		1.08		1.05														
13		●1.59		.96						EXPENDED AD FLT 4		EXPENDED AD FLT 2	EXPENDED AD FLT 3	EXPENDED AD FLT 1				EXPENDED AD FLT 5
14		●1.41		.72														
15		●1.48		.73														
16		●1.57		●1.33														
17		●1.39		●7.40														
18		●1.36		●1.12														
19		●1.18																
20		●1.77																
21		●1.40																
22		●1.43																
23		.63																
24		●1.48																
25		.50																
26		●18.62																
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		

● CONTAINS FLIGHT PARAMETER > 3 σ

APPENDIX

CALIBRATION TREND ANALYSIS

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One method that is widely used to examine data for trending effects is linear regression.[2] A straight line of the form

$$Y = A + BX \tag{1}$$

is fitted to the data such that the sum of squares of vertical deviations of the observed data from this line is smaller than the corresponding sum for any other straight line. The regression line is therefore a least-square estimate of the unknown true line. Equation (1) is the familiar slope/intercept form with

$$B = \frac{N\Sigma XY-\Sigma X\Sigma Y}{N\Sigma X^2-(\Sigma X)^2} \tag{2}$$

and

$$A = \frac{\Sigma Y-B\Sigma X}{N} \tag{3}$$

in which

N = number of data point pairs

X = independent variable

Y = dependent variable (observed data, each value paired with a corresponding value of X)

Σ = summation of indicated variables over all data points from 1 to N.

After determination of A and B it is a simple matter to use Equation (1) to provide an estimate of Y for a new specified value of X. Alternately, X can be calculated for any value of Y:

$$X = \frac{Y-A}{B} \tag{4}$$

2. US Naval Ordnance Test Station; Statistics Manual by Crowe, E. L., David, F. A., and Maxfield, Margaret W., China Lake, California, 1955, Chapter 6.

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Equation (4) provides an optimistic estimate of X because the actual Y data is scattered about the regression line. The scatter is measured by

$$S_{yx}^2 = \frac{N-1}{N-2}\left(S_y^2 - B^2 S_x^2\right) \tag{5}$$

and the positive square root is sometimes called the standard error of the estimate.

In Equation (5)

$$S_y^2 = \frac{N\Sigma Y^2 - (\Sigma Y)^2}{N(N-1)} \tag{6}$$

and

$$S_x^2 = \frac{N\Sigma X^2 - (\Sigma X)^2}{N(N-1)} \tag{7}$$

which are the Y and X variances about their respective means.

If the Y data corresponding to the various Xs is normally distributed about the true regression line, two lines drawn parallel to the calculated regression line at vertical distances $\pm S_{yx}$ envelop 68 percent of the data. These lines are defined by

$$Y = (A+S_{yx})+BX \tag{8}$$

and

$$Y = (A-S_{yx})+BX \tag{9}$$

and are illustrated in Figure A-1. If it is desired to estimate a maximum X for an assumed value of Y, e.g., Y_1 in Figure A-1, the conservative approach would be to use Equation (8) or the top line of Figure A-1 to account for some of the variation about the calculated regression line. Thus X_1 would be the conservative estimate.

Further conservatism may be applied to the estimate by consideration of the standard error of the slope which is given by

$$S_B = \frac{S_{yx}}{S_x \sqrt{N-1}} \tag{10}$$

Equation (10) allows for variations of the slope B and is used to define two lines given by

$$Y = A+(B+S_B)X \tag{11}$$

and

$$Y = A+(B-S_B)X \tag{12}$$

which are illustrated in Figure A-2. Again X_I would be the conservative estimate for a given value of Y_I.

Allowance for variation of slope and variation of data about the line of chosen slope can be made by combining elements of Equations (8) and (11) and Equations (9) and (12) to give

$$Y = (A+S_{yx}) + (B+S_B)X \tag{13}$$

and

$$Y = (A-S_{yx}) + (B-S_B)X \tag{14}$$

Plots of Equations (13) and (14), as shown in Figure A-3, provide a funnel about the original regression line and should enclose practically all of the observed data.

Equation (13) provides the most conservative estimate of X for any of the cases considered when the slope B is positive as indicated in Figure A-3.

Similarly, when the slope is negative, Equation (14) provides the conservative estimate.

The criterion for the estimation of a conservative value of X when $Y = \pm Y_1$ is thus established as

$$X_1 = \frac{\pm Y_1 - (A \pm S_{yx})}{(B \pm S_B)} \tag{15}$$

in which the sign of Y_1, S_{yx} and S_B is taken the same as the sign of the slope B.

In the case of the PII IMU calibration trend analysis, an estimate of X (months) is sought which indicates when $\pm Y_1 = \pm 3$ sigma since the ± 3 sigma limits specify the unqualified requirement for a new calibration under AD ground rules.

The linear regression line as given in Equation (1) was established for each parameter from all IMUs having six or more calibrations over a period of six or more months (serial numbers 001, 002, 003 and 005). Equation (15) was used to calculate a conservative estimate of $X = X_1$ (months) which would be expected to elapse before a parameter exceeded its ± 3 sigma limits thus giving an indication of the amount of time that may be allowed between calibrations.

Figures A-4 through A-37 show data obtained for each parameter from IMU serial number 005 and the corresponding regression lines given by Equation (1). Also shown are the lines specified by Equations (13) and (14).

Other statistics computed from calibration data from those IMUs analyzed are:

(1) Correlation coefficient:

$$R = BS_x/S_y \tag{16}$$

with B given by Equation (2) and S_y and S_x given by the respective square roots of Equations (6) and (7).

(2) Root mean square error of the dependent variable:

$$Y(RMS) = (\Sigma Y^2/N)^{\frac{1}{2}} \tag{17}$$

with symbol definitions the same as those given for Equations (2) and (3).

(3) Average error of the dependent variable:

$$Y(AVG) = \Sigma Y/N \tag{18}$$

with symbol definitions the same as those given for Equations (2) and (3).

Computed values of all statistics for each calibration parameter from IMUs with serial numbers 001, 002, 003 and 005 along with conservative estimate, X, and estimate, X_Z, from the original regression line, are compiled in Tables A-1 through A-4 respectively.

Resulting values of the conservative estimate, X_1, are summarized in Table A-5 which also shows the values of X_1 for each parameter averaged over the four IMUs analyzed.

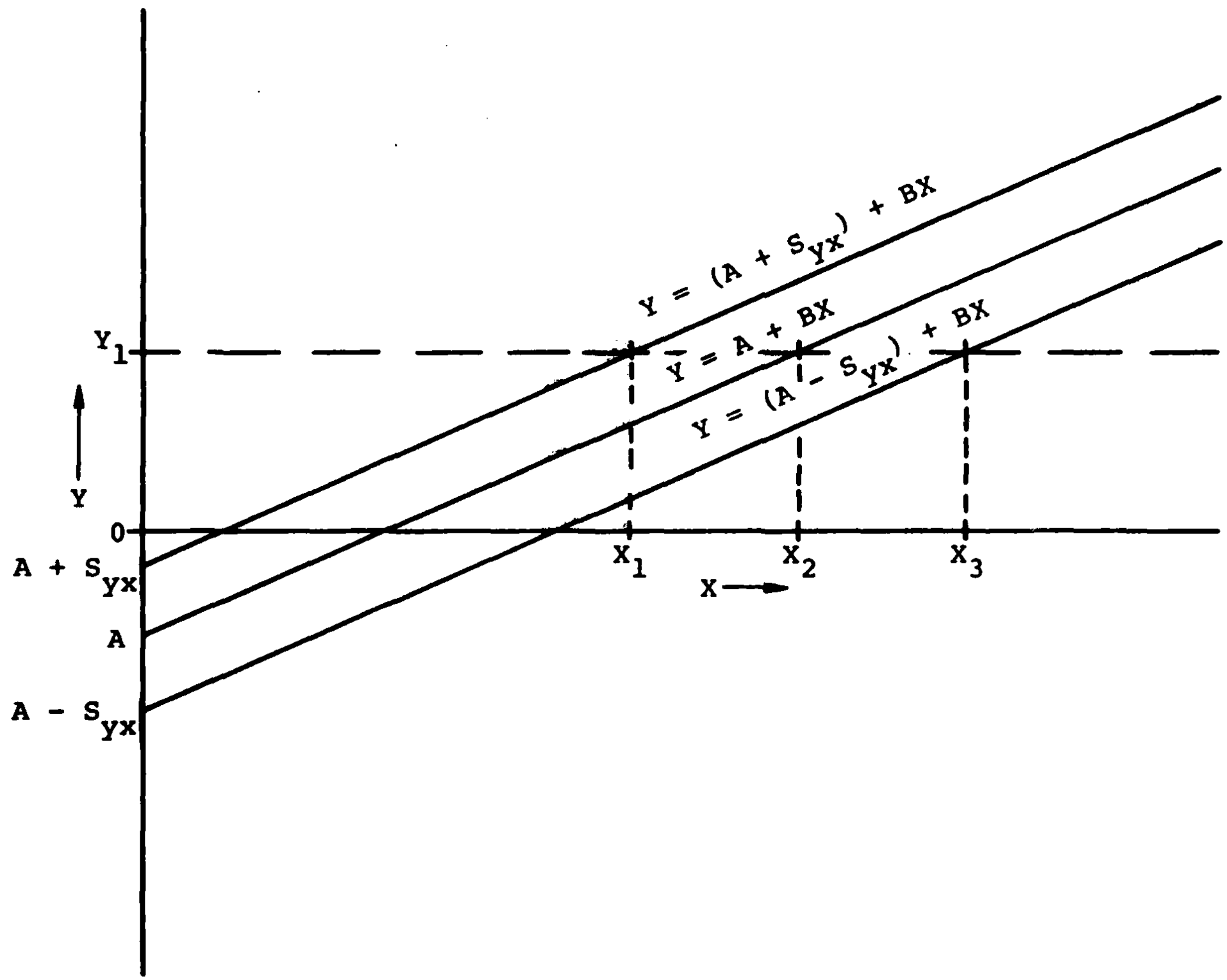


Figure A-1. Linear regression lines showing $\pm$ S_{yx} bounds.

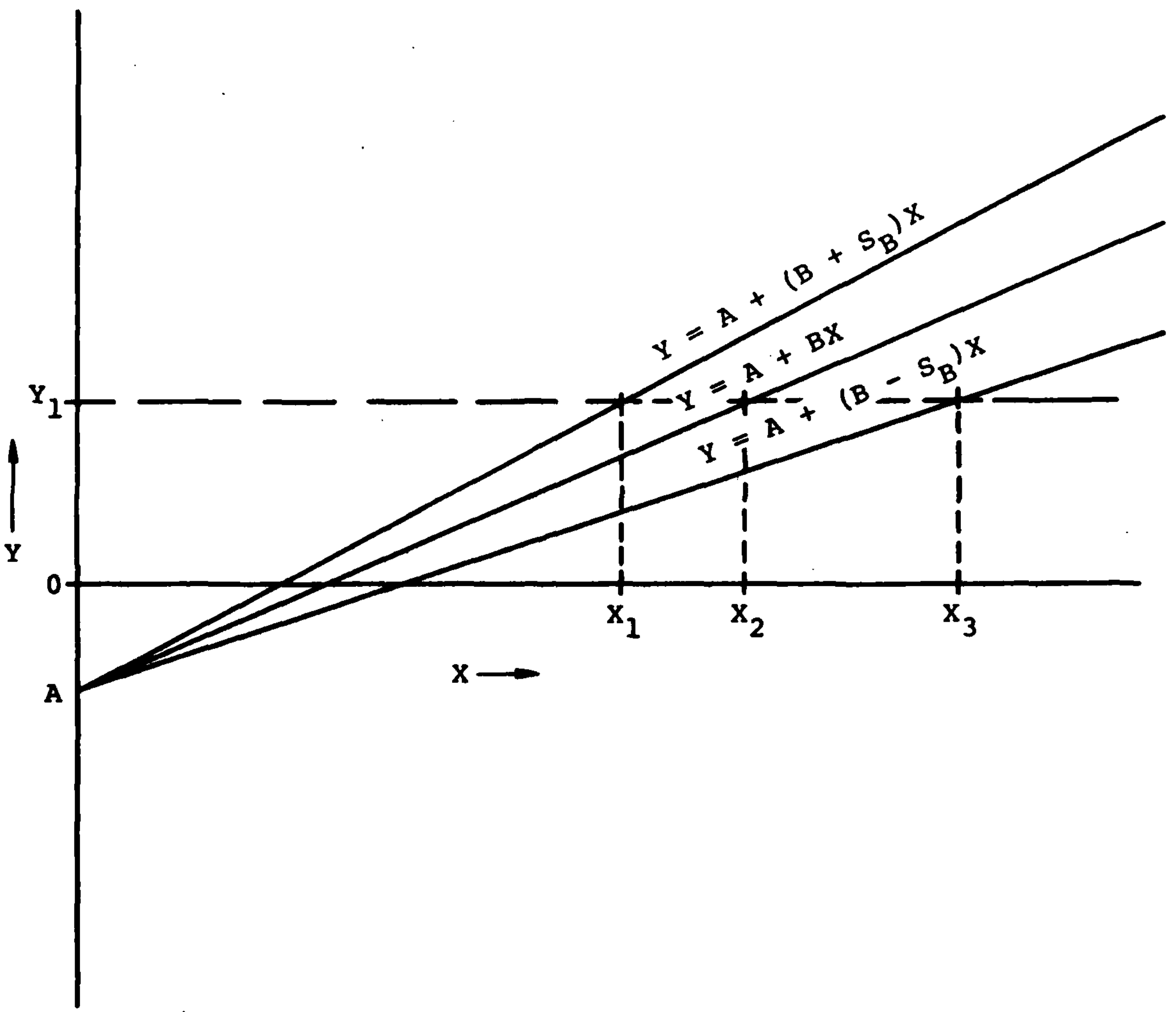


Figure A-2. Linear regression lines showing $\pm S_B$ bounds.

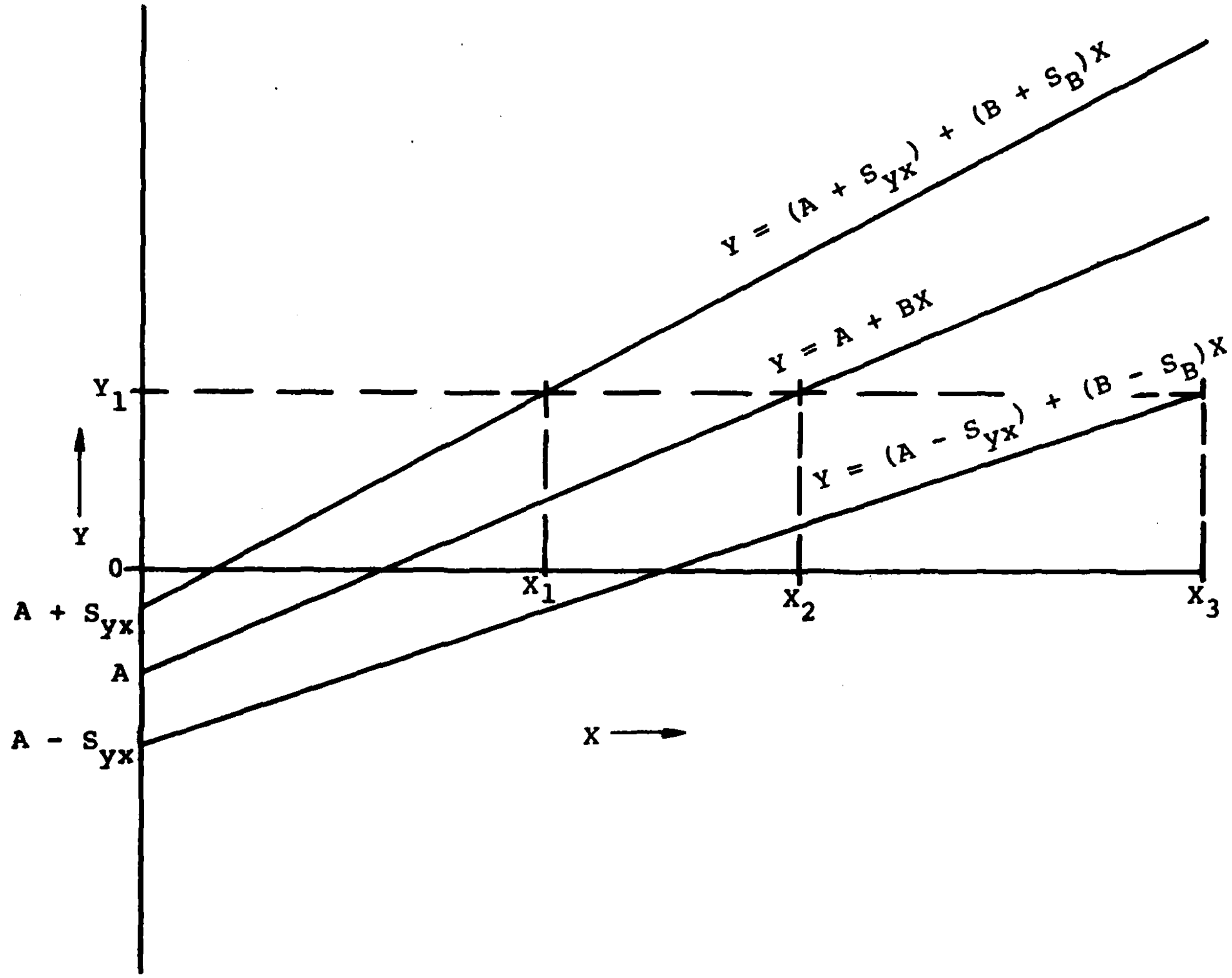


Figure A-3. Linear regression lines allowing for S_{yx} and S_B.

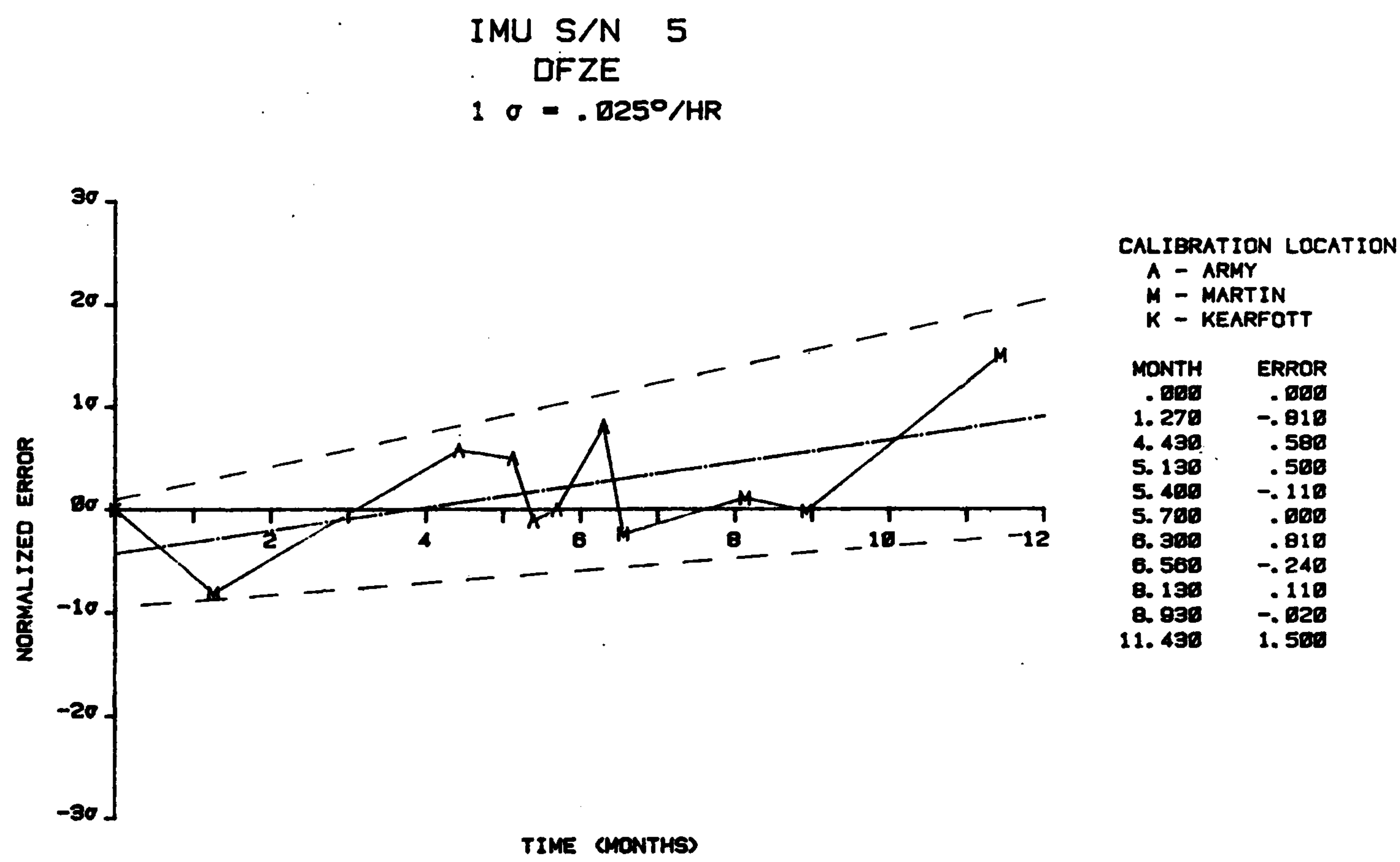
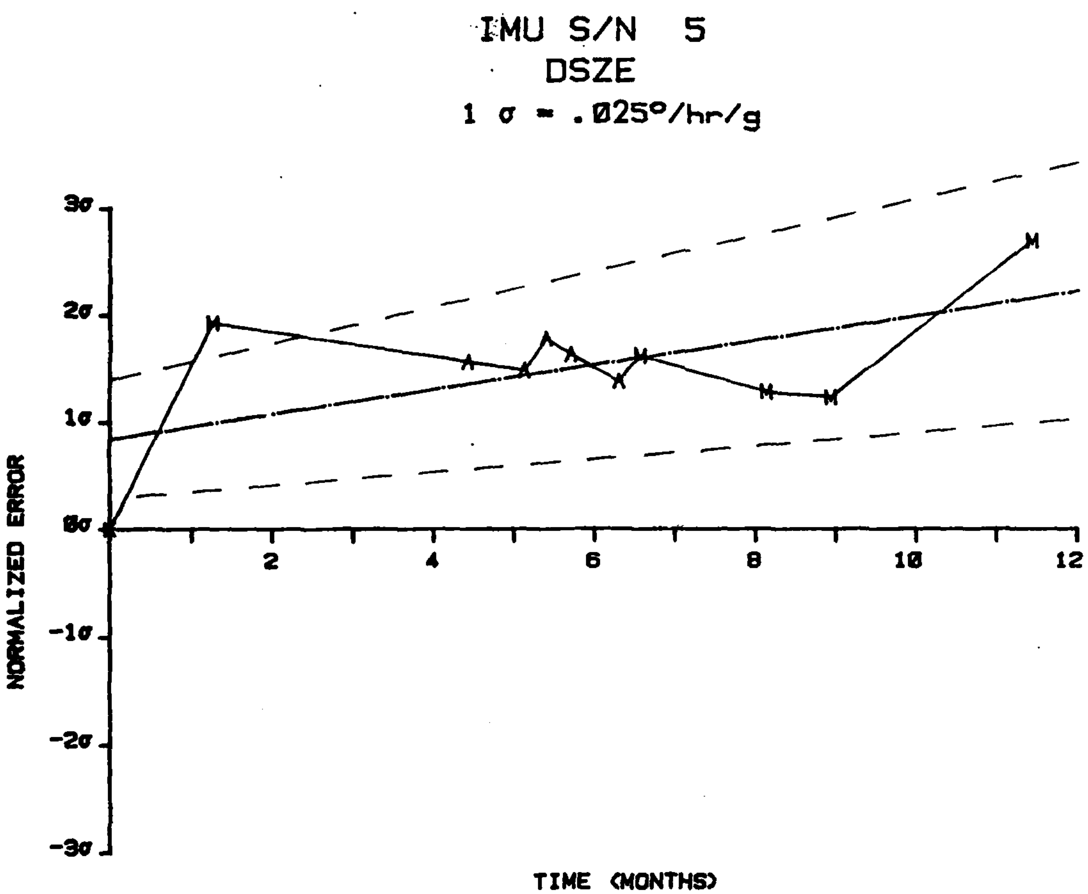


Figure A-4. DFZE.



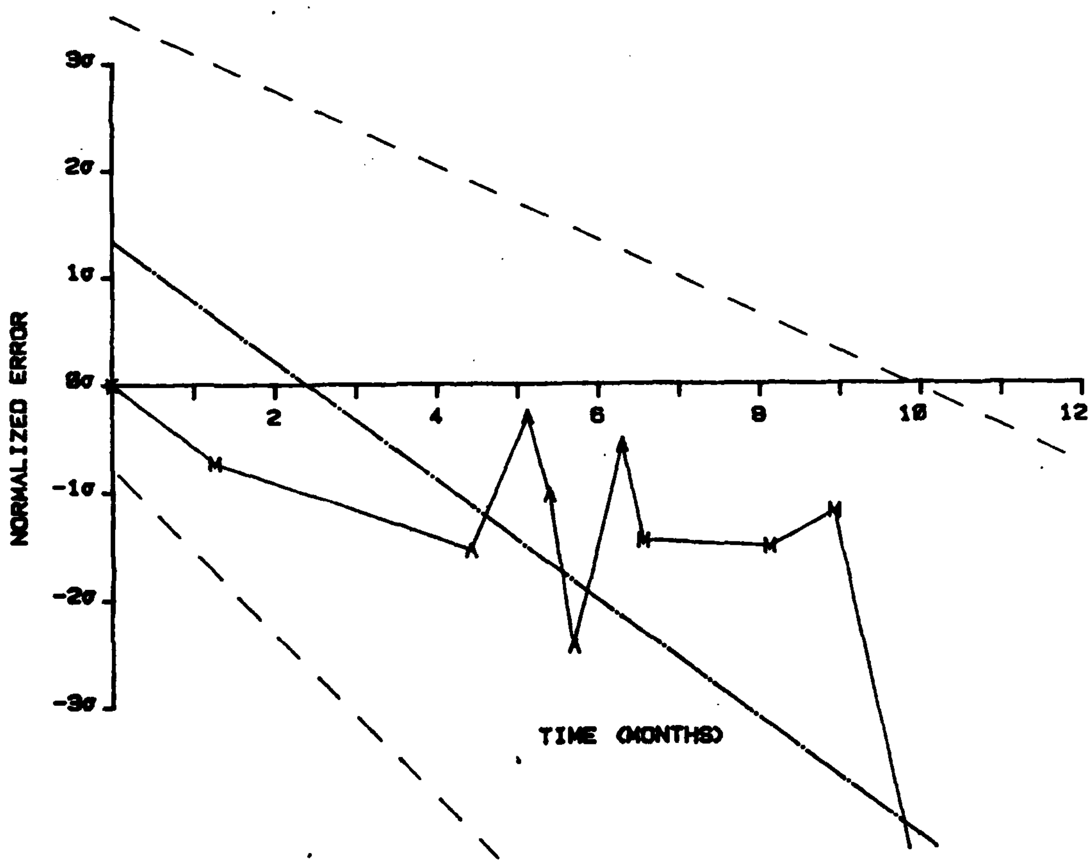
MONTH	ERROR
.ØØØ	.ØØØ
1.27Ø	1.93Ø
4.43Ø	1.56Ø
5.13Ø	1.48Ø
5.4ØØ	1.78Ø
5.7ØØ	1.63Ø
6.3ØØ	1.38Ø
6.56Ø	1.62Ø
8.13Ø	1.28Ø
8.93Ø	1.23Ø
11.43Ø	2.7ØØ

Figure A-5. DSZE.

IMU S/N 5

DIZE

1 σ = .03°/hr/g

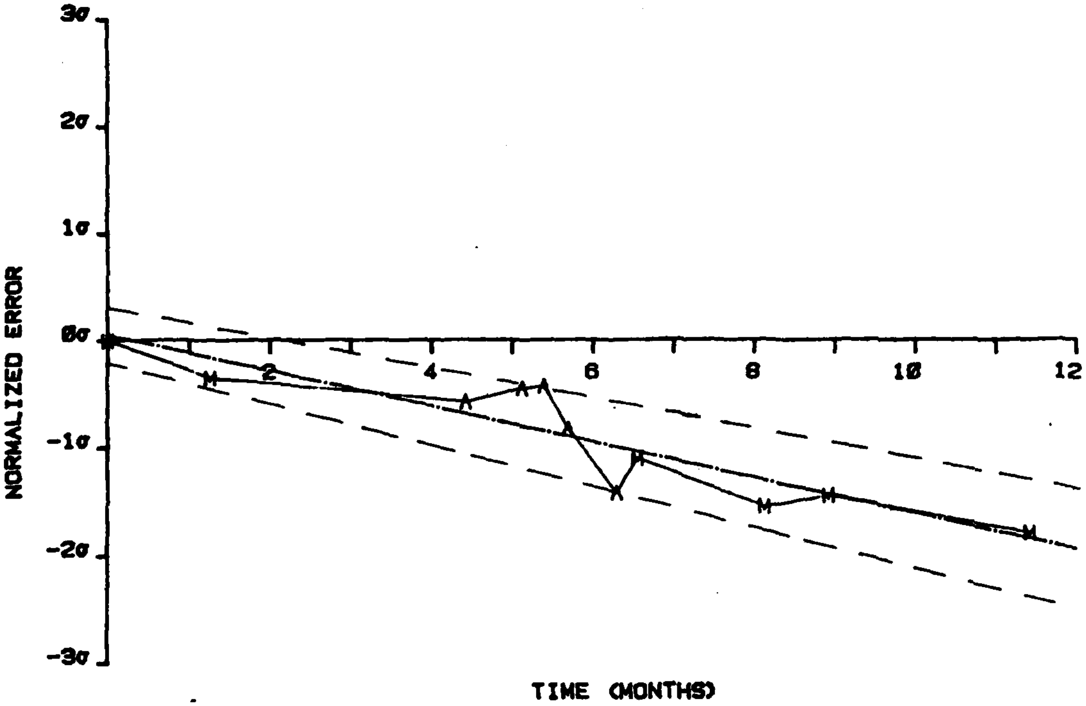


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.730
4.430	-1.530
5.130	-.300
5.400	-1.030
5.700	-2.430
6.300	-.563
6.560	-1.450
8.130	-1.510
8.930	-1.190
11.430	-9.700

Figure A-6. DIZE.

IMU S/N 5
KIYE
1 σ = 100 ug/g

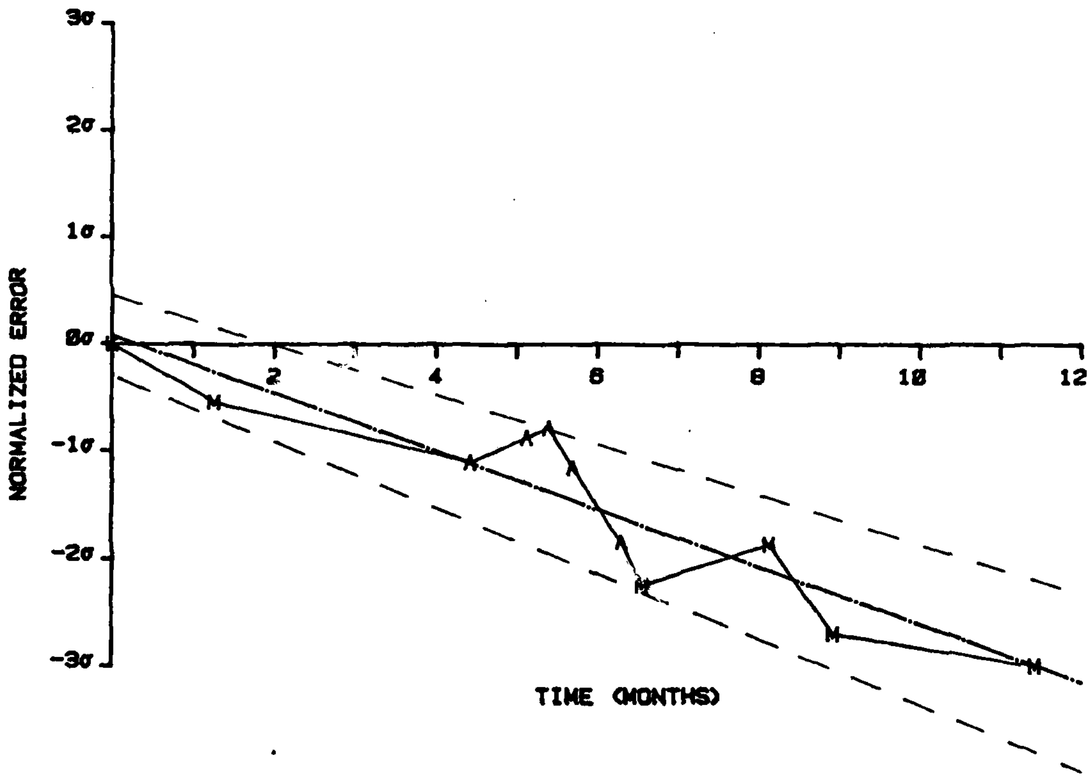


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.352
4.430	-.577
5.130	-.450
5.400	-.420
5.700	-.820
6.300	-1.420
6.560	-1.100
8.130	-1.550
8.930	-1.450
11.430	-1.800

Figure A-7. KIYE.

IMU S/N 5
KIYHE
$1\ \sigma = 100\ ug/g$

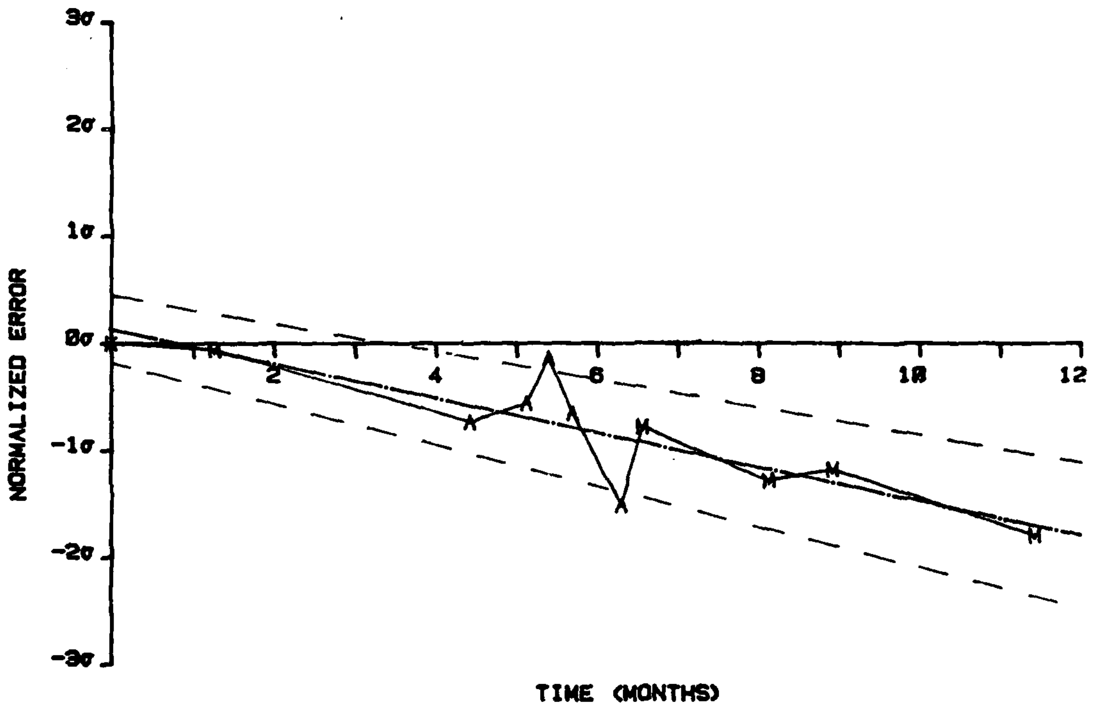


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.540
4.430	-1.100
5.130	-.870
5.400	-.780
5.700	-1.150
6.300	-1.840
6.560	-2.240
8.130	-1.860
8.930	-2.700
11.430	-3.000

Figure A-8. KIYHE.

IMU S/N 5
KIXE
1 σ = 100 ug/g

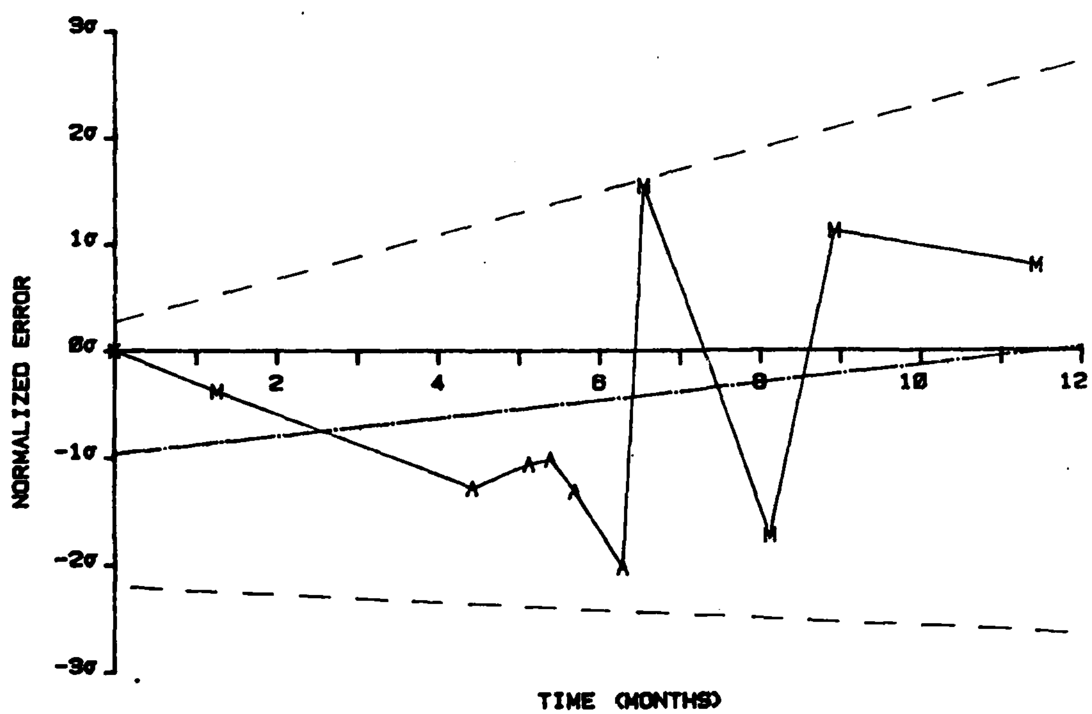


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.060
4.430	-.730
5.130	-.560
5.400	-.140
5.700	-.650
6.300	-1.510
6.560	-.780
8.130	-1.280
8.930	-1.180
11.430	-1.800

Figure A-9. KIXE.

IMU S/N 5
KIXHE
$1\sigma = 100\ \mu g/g$

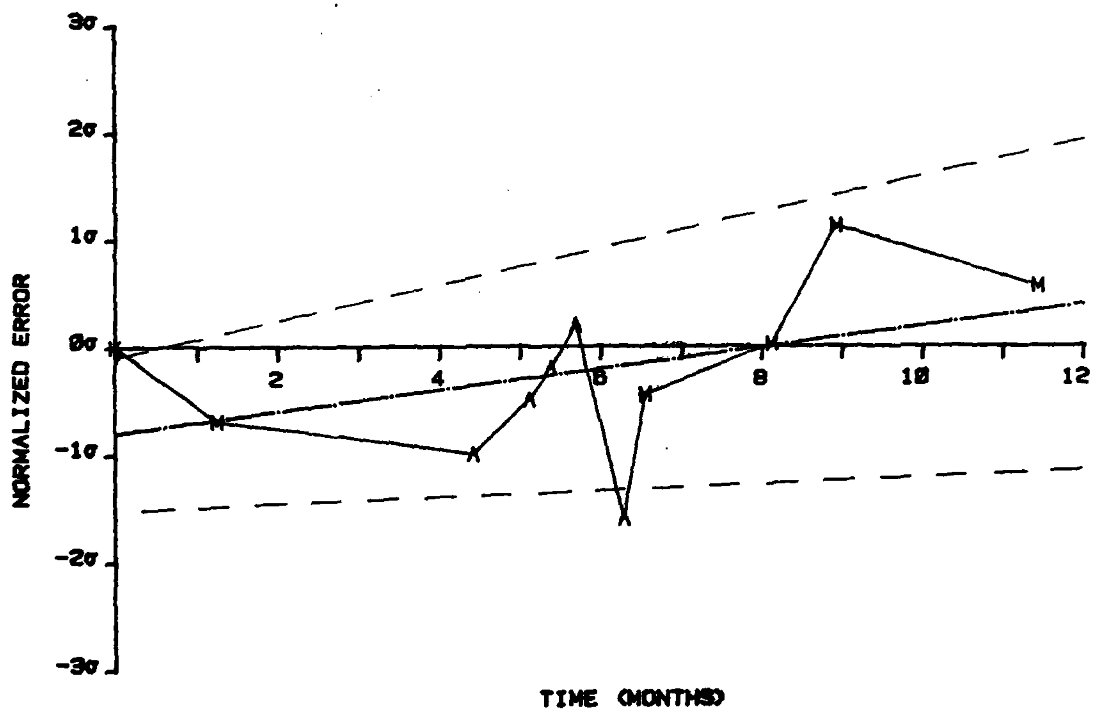


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.380
4.430	-1.280
5.130	-1.060
5.400	-1.020
5.700	-1.310
6.300	-2.020
6.560	1.550
8.130	-1.720
8.930	1.120
11.430	.800

Figure A-10. KIXHE.

IMU S/N 5
DOZE
$1\ \sigma = .02°/hr/g$

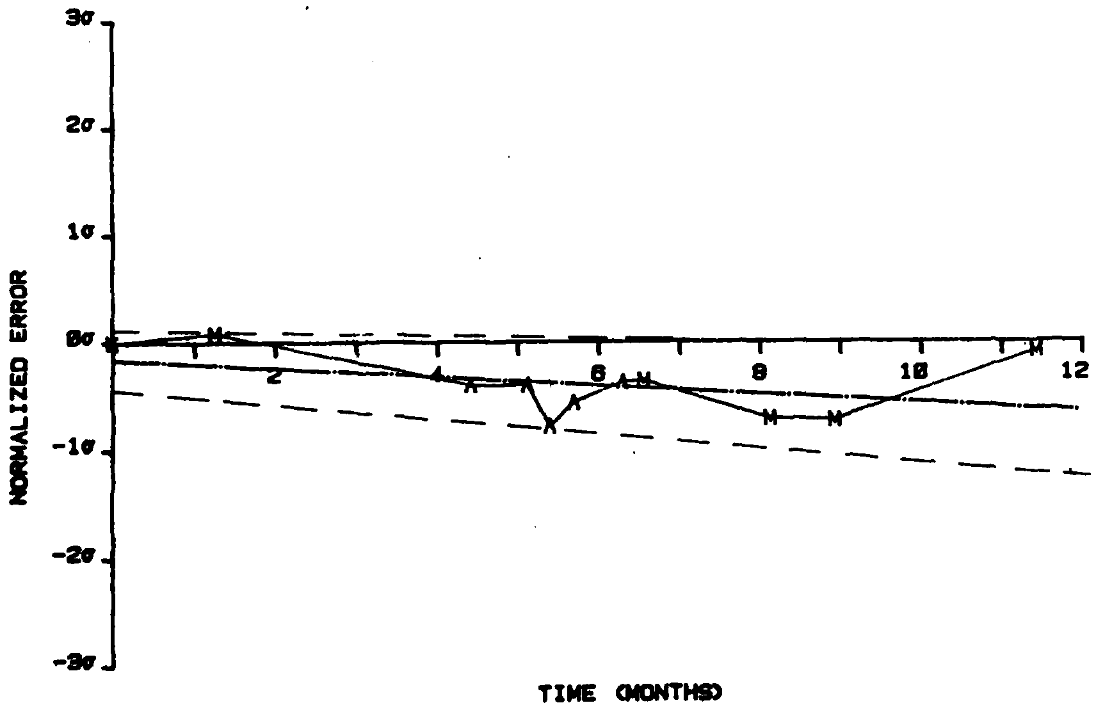


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.700
4.430	-1.000
5.130	-.500
5.400	-.200
5.700	.200
6.300	-1.600
6.560	-.450
8.130	.025
8.930	1.120
11.430	.560

Figure A-11. DOZE.

IMU S/N 5
DFXE
1 σ = .Ø25°/hr

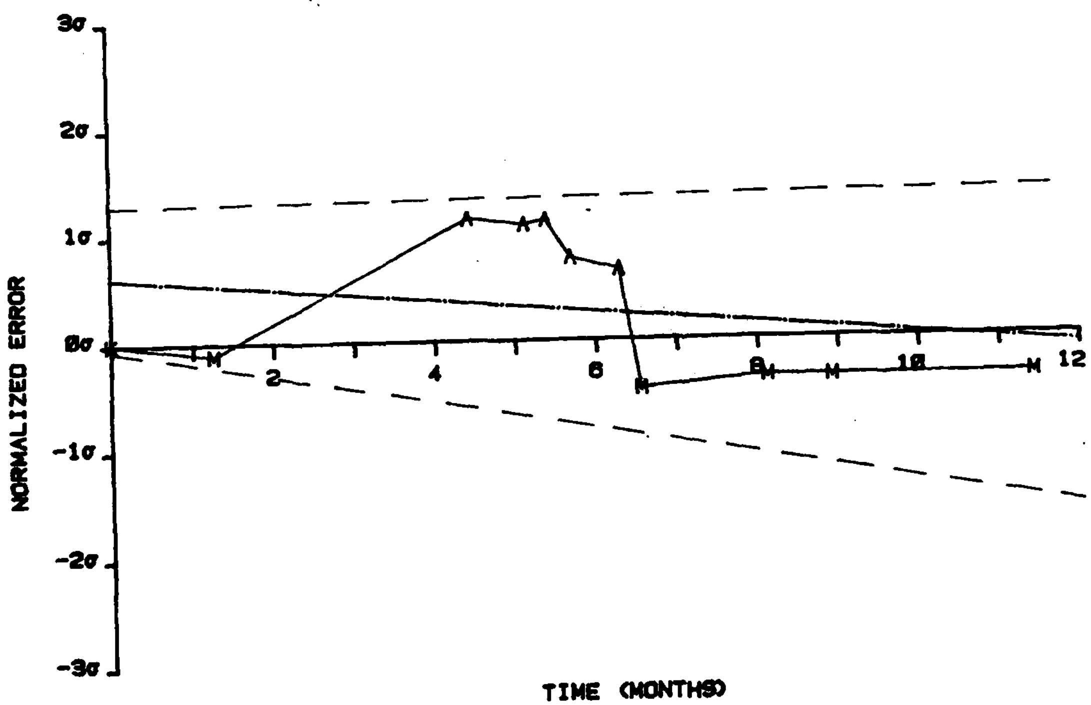


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.ØØØ	.ØØØ
1.27Ø	.Ø84
4.43Ø	-.4Ø4
5.13Ø	-.4ØØ
5.4ØØ	-.788
5.7ØØ	-.564
6.3ØØ	-.376
6.56Ø	-.36Ø
8.13Ø	-.72Ø
8.93Ø	-.73Ø
11.43Ø	-.Ø9Ø

Figure A-12. DFXE.

IMU S/N 5
KIZE
1 σ = 100ug/g

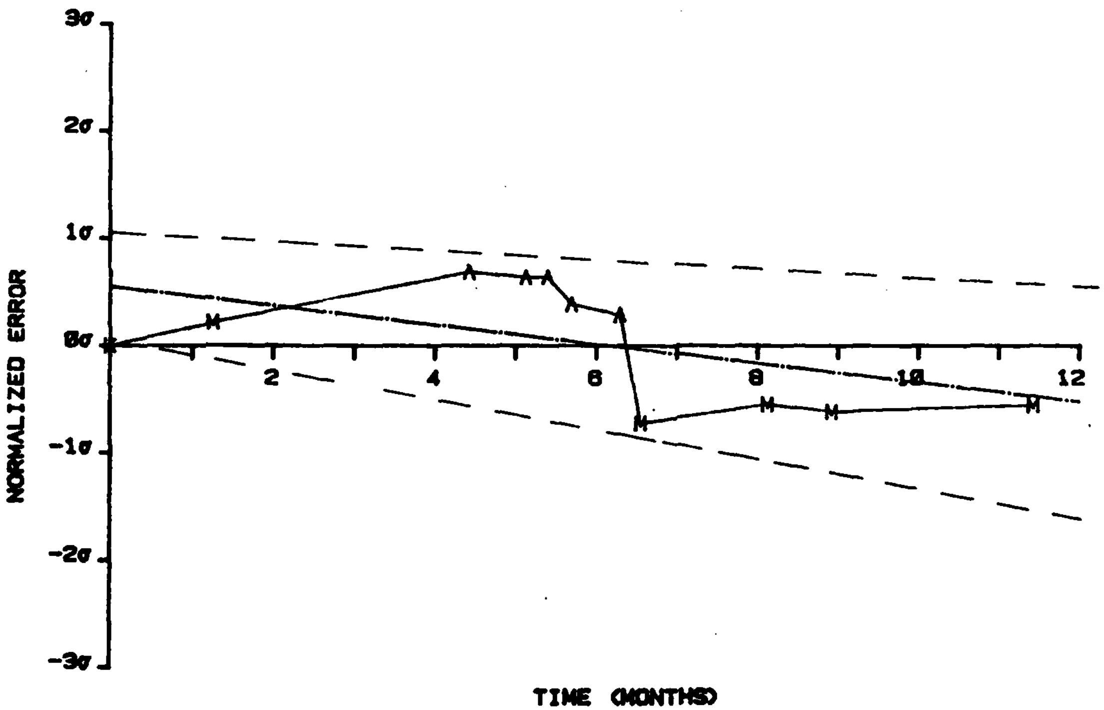


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.118
4.430	1.137
5.130	1.081
5.400	1.120
5.700	.765
6.300	.653
6.560	-.462
8.130	-.358
8.930	-.368
11.430	-.368

Figure A-13. KIZE.

IMU S/N 5
KIZHE
1 σ = 100 ug/g



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.217
4.430	.690
5.130	.641
5.400	.644
5.700	.386
6.300	.289
6.560	-.724
8.130	-.551
8.930	-.620
11.430	-.560

Figure A-14. KIZHE.

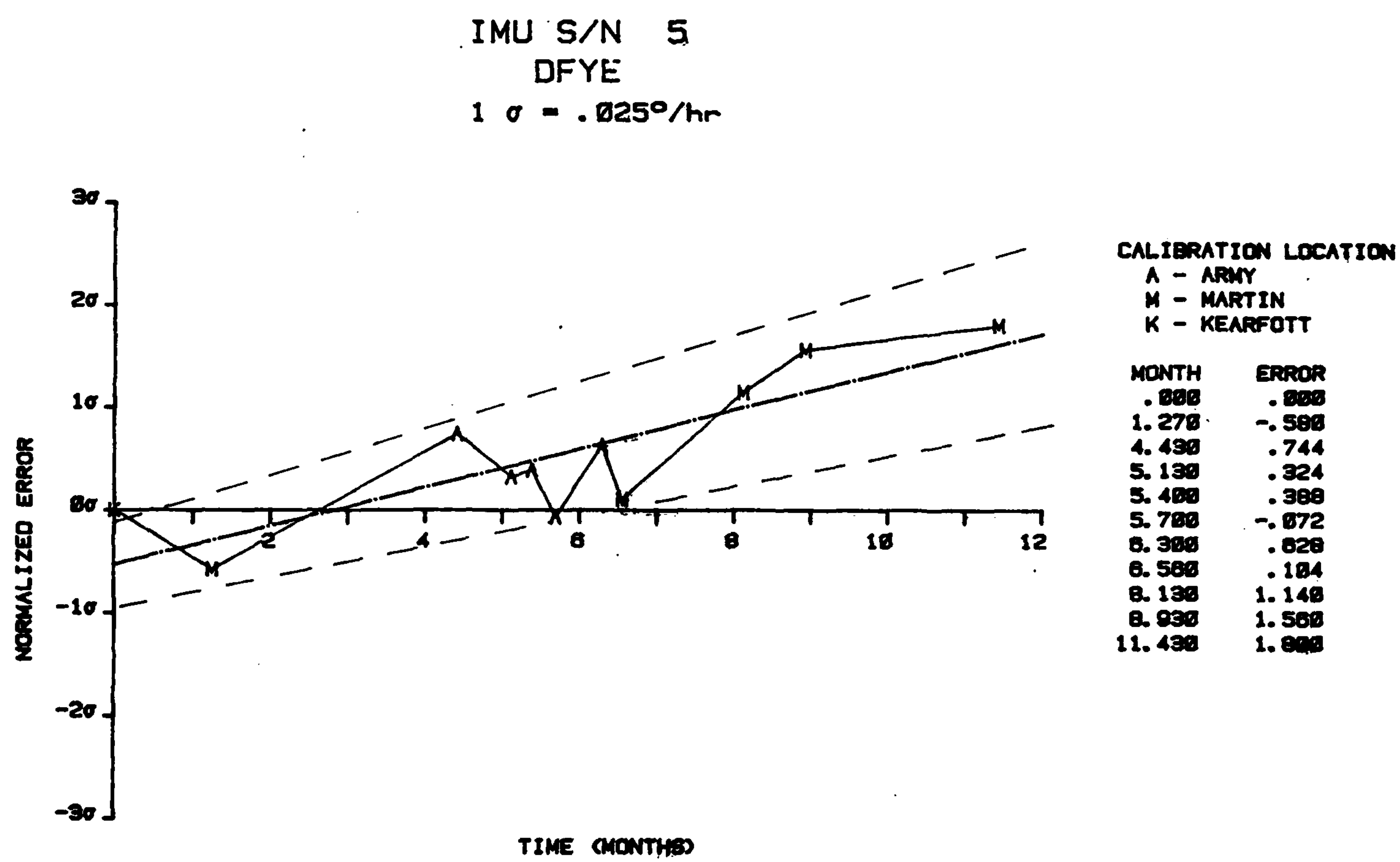
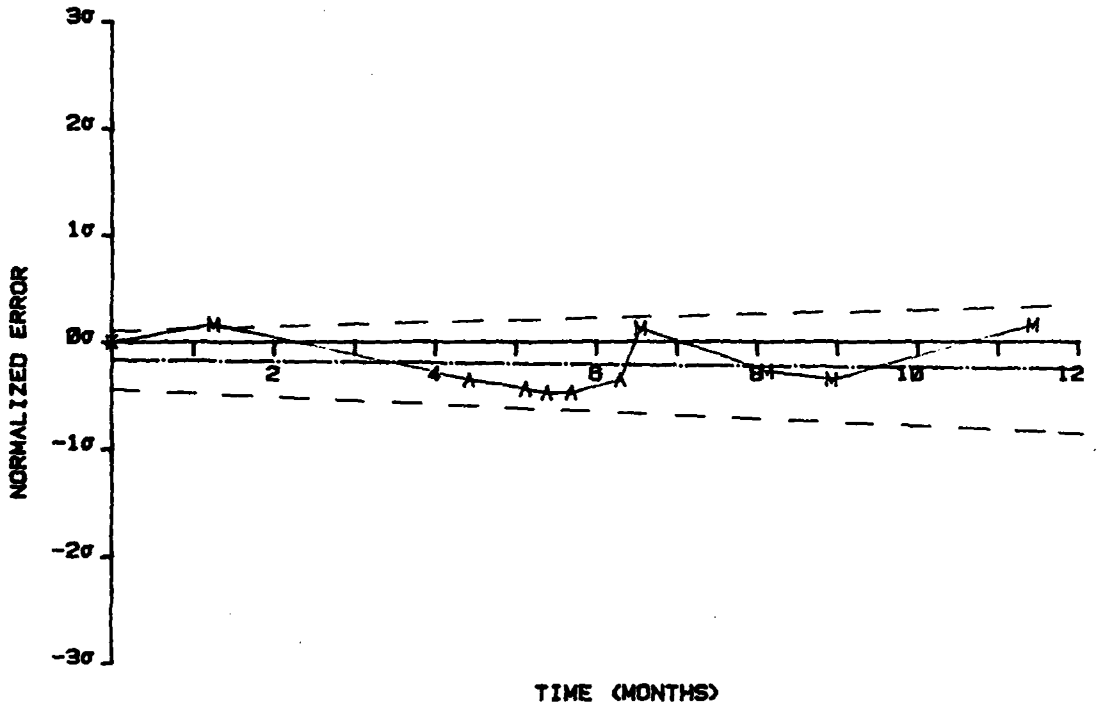


Figure A-15. DFYE.

IMU S/N 5
DSXE
1 σ = .025°/hr/g



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

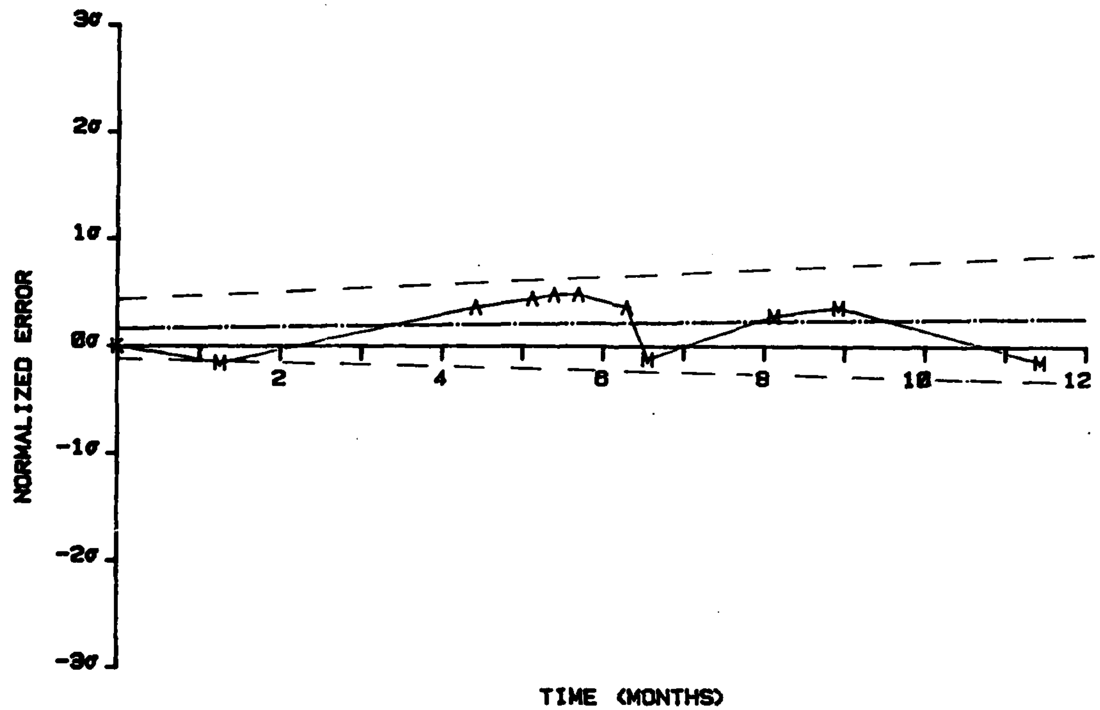
MONTH	ERROR
.000	.000
1.270	.160
4.430	-.360
5.130	-.440
5.400	-.480
5.700	-.480
6.300	-.360
6.560	.120
8.130	-.280
8.930	-.360
11.430	.150

Figure A-16. DSXE.

IMU S/N 5

DSYE

1 σ = .025°/hr/g

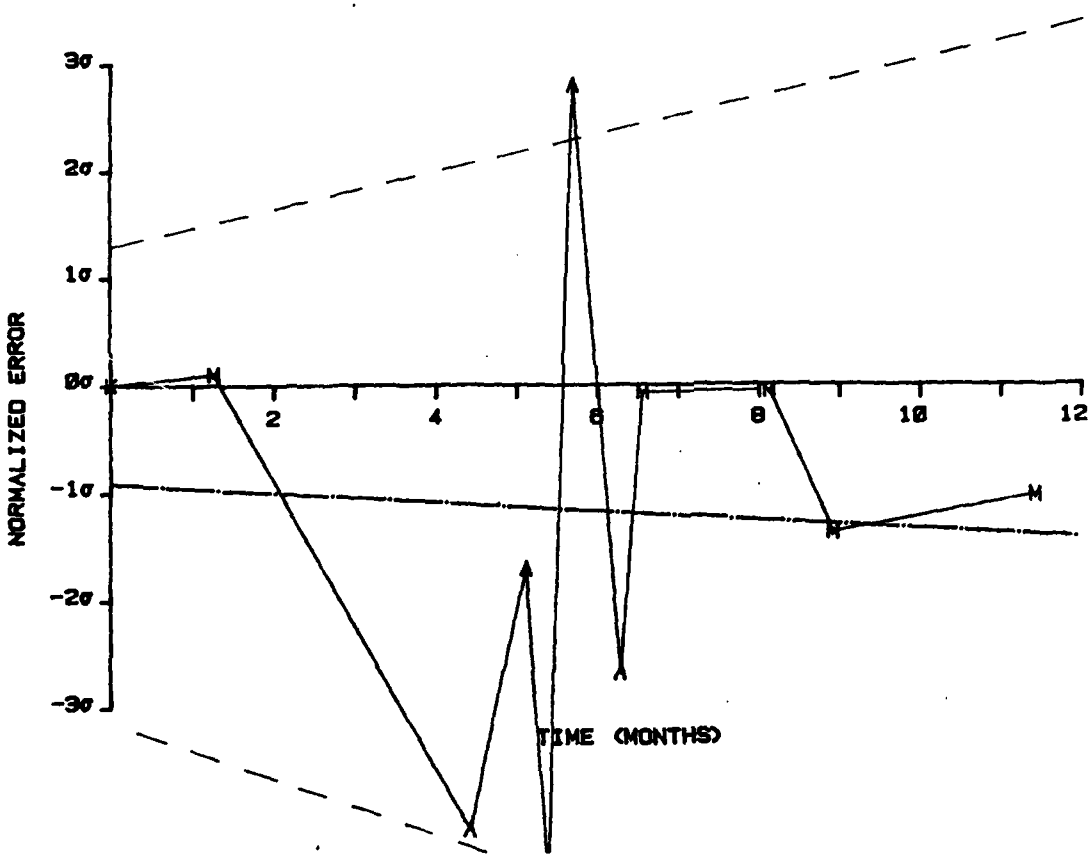


CALIBRATION LOCATION
- A - ARMY
- M - MARTIN
- K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.160
4.430	.360
5.130	.440
5.400	.480
5.700	.480
6.300	.360
6.560	-.120
8.130	.280
8.930	.360
11.430	-.150

Figure A-17. DSYE.

IMU S/N 5
DIXE
1 σ = .03°/hr/g



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.100
4.430	-4.130
5.130	-1.700
5.400	-4.600
5.700	2.800
6.300	-2.670
6.560	-.070
8.130	-.060
8.930	-1.370
11.430	-1.040

Figure A-18. DIXE.

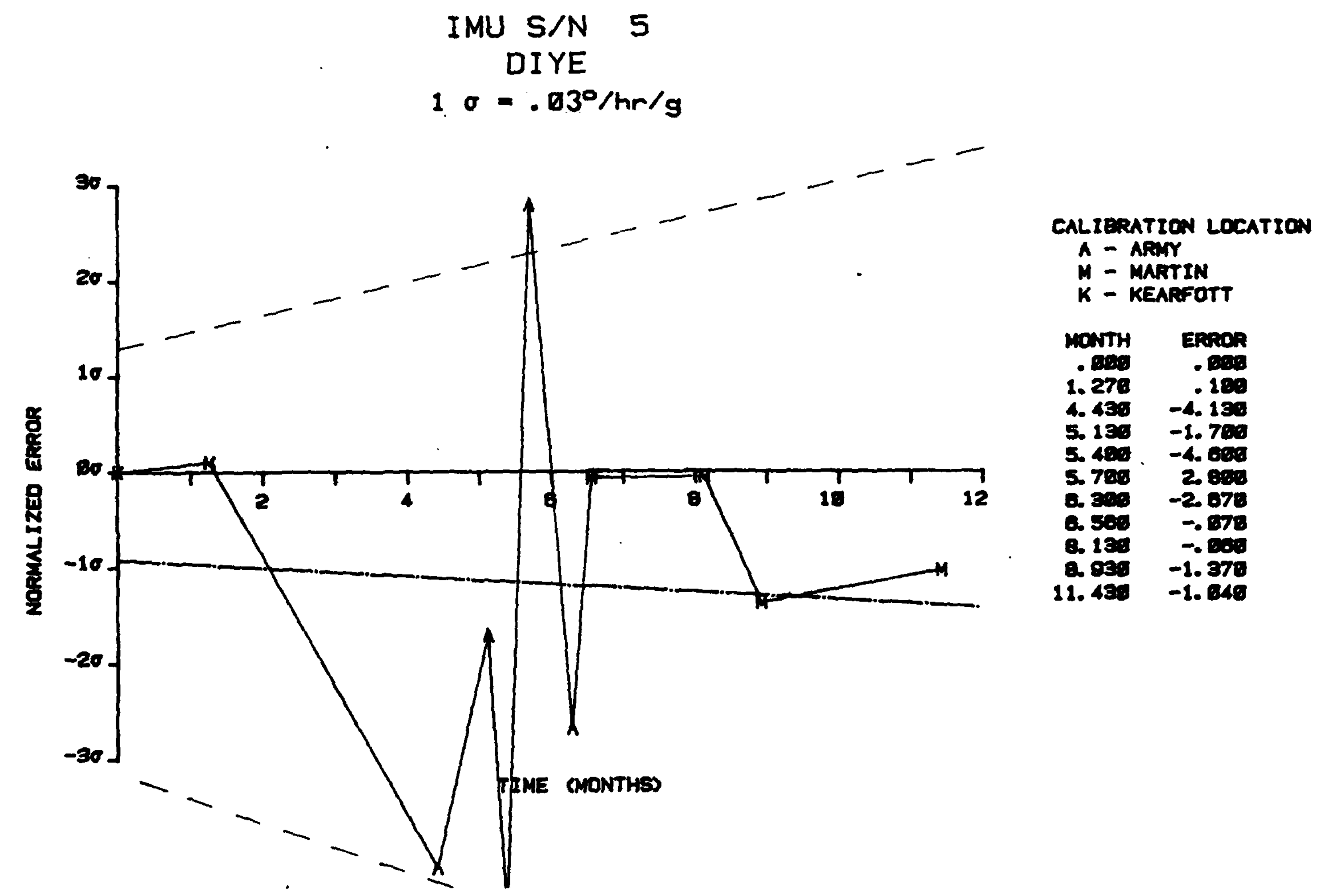
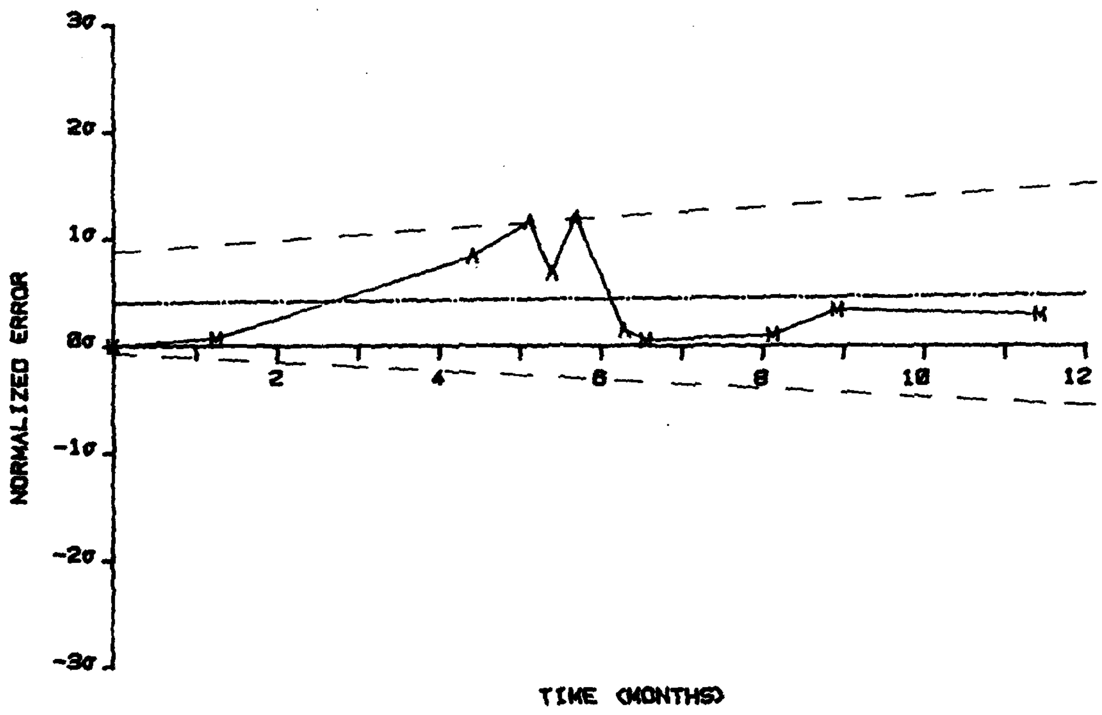


Figure A-19. DIYE.

IMU S/N 5
DELTA YX
1 σ = .00008 rad

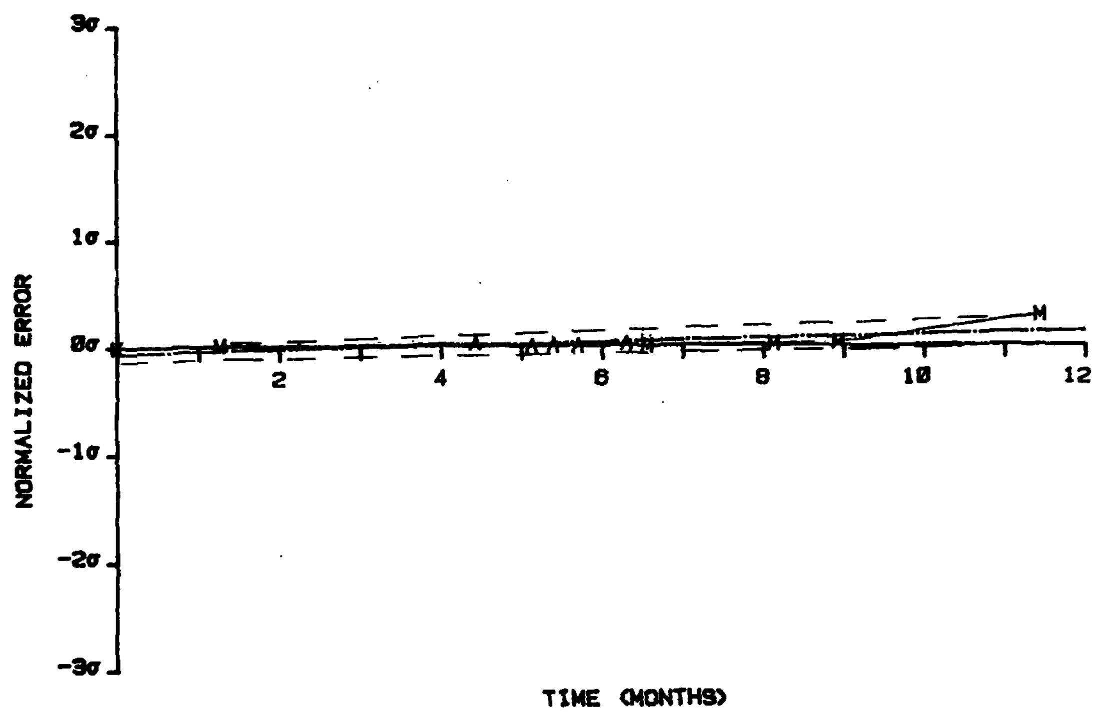


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.070
4.430	.840
5.130	1.160
5.400	.680
5.700	1.200
6.300	.140
6.560	.050
8.130	.100
8.930	.340
11.430	.290

Figure A-20. DELTA YX.

IMU S/N 5
DELTA ZY
1 σ = .00020 rad

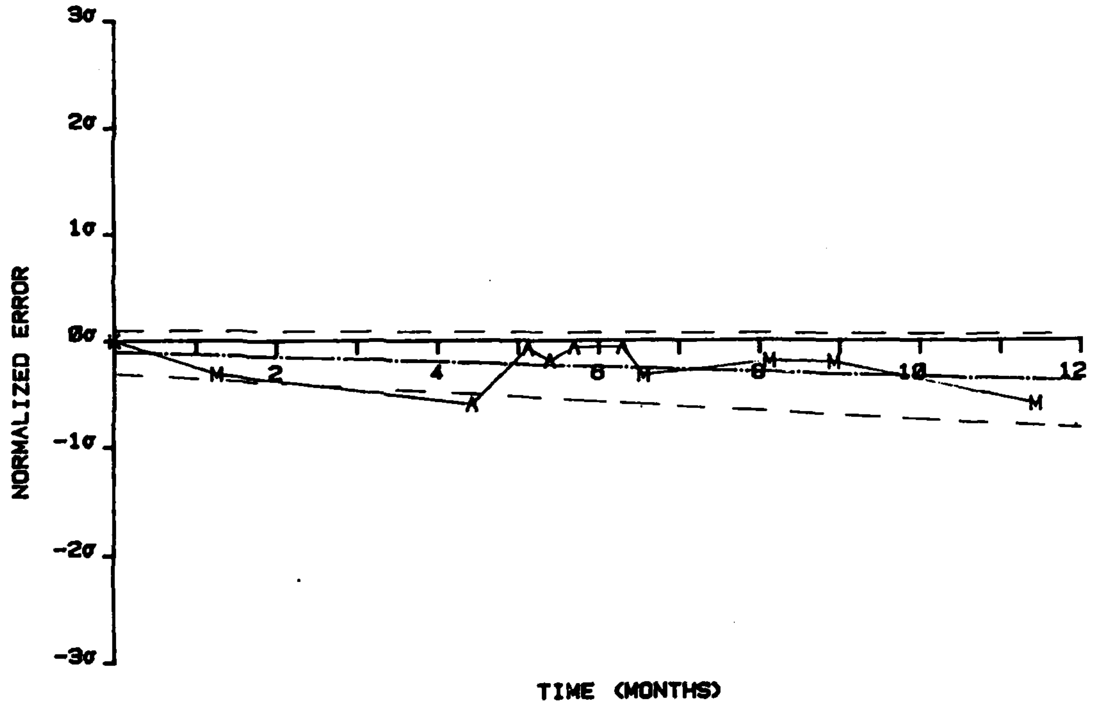


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.010
4.430	.030
5.130	.001
5.400	.006
5.700	.004
6.300	.020
6.560	.002
8.130	.020
8.930	.030
11.430	.200

Figure A-21. DELTA ZY.

IMU S/N 5
KOZE
1 σ = 300 ug



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

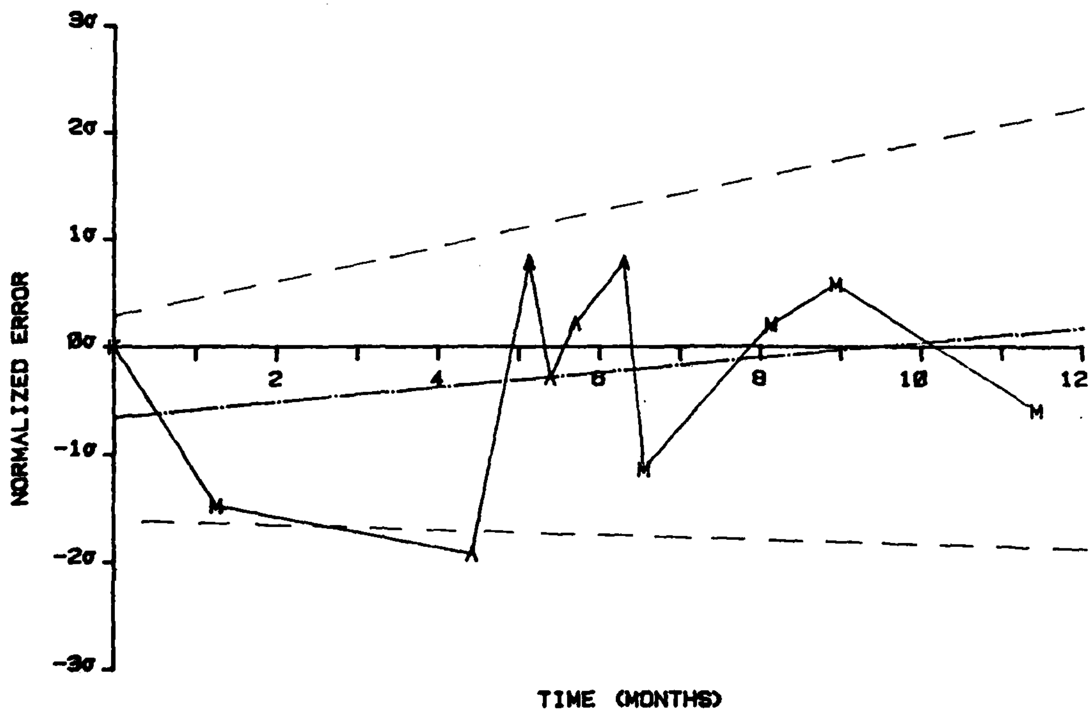
MONTH	ERROR
.000	.000
1.270	-.310
4.430	-.600
5.130	-.070
5.400	-.190
5.700	-.060
6.300	-.060
6.560	-.320
8.130	-.190
8.930	-.200
11.430	-.600

Figure A-22. KOZE.

IMU S/N 5

KSZE

1 σ = 5Ø ug/g

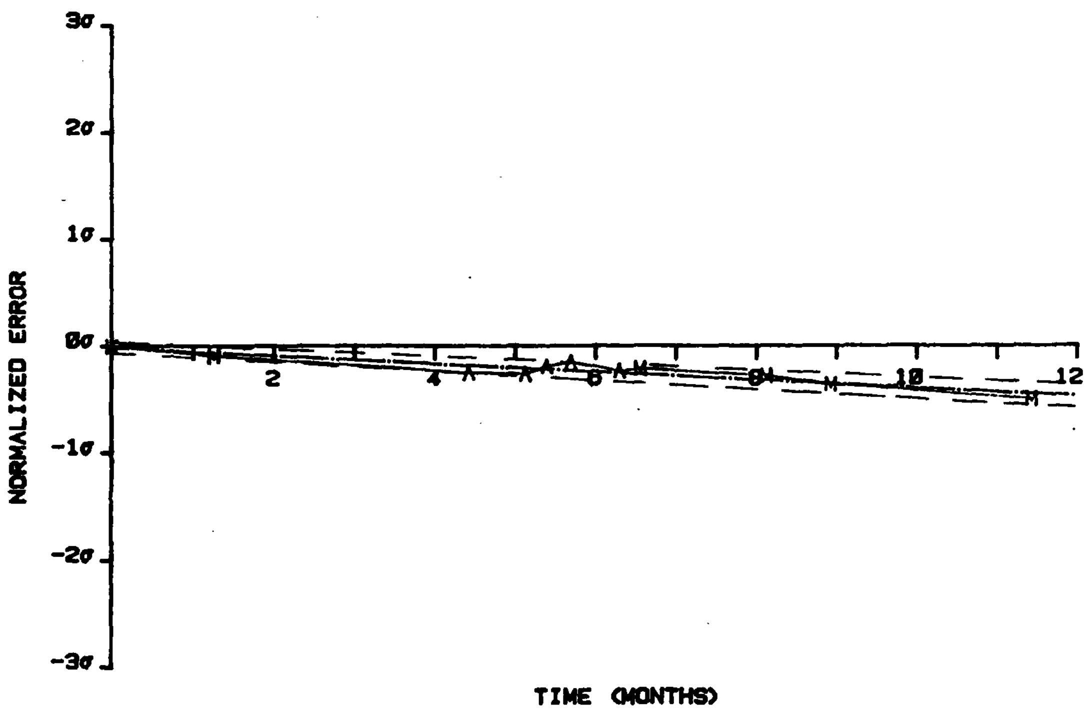


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.ØØØ	.ØØØ
1.27Ø	-1.47Ø
4.43Ø	-1.92Ø
5.13Ø	.8ØØ
5.4ØØ	-.29Ø
5.7ØØ	.22Ø
6.3ØØ	.79Ø
6.56Ø	-1.13Ø
8.13Ø	.21Ø
8.93Ø	.59Ø
11.43Ø	-.8ØØ

Figure A-23. KSZE.

IMU S/N 5
KOZHE
$1\ \sigma = 300$ ug

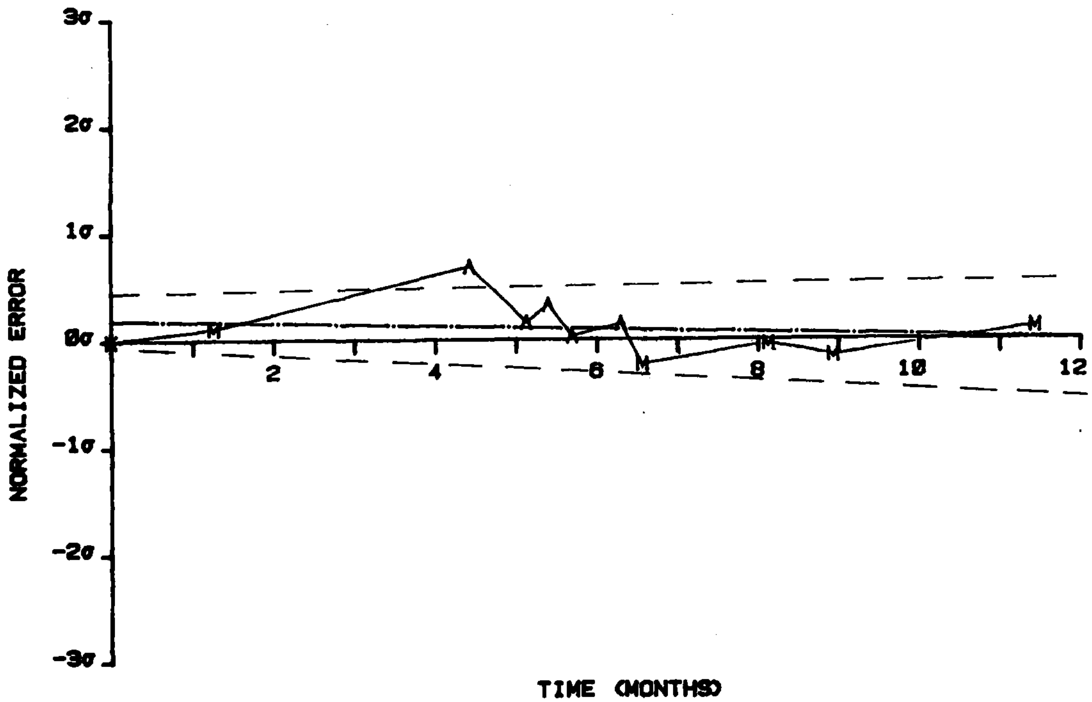


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.090
4.430	-.250
5.130	-.260
5.400	-.190
5.700	-.150
6.300	-.230
6.560	-.210
8.130	-.280
8.930	-.360
11.430	-.500

Figure A-24. KOZHE.

IMU S/N 5
KSZHE
$1\ \sigma = 50$ ug/g

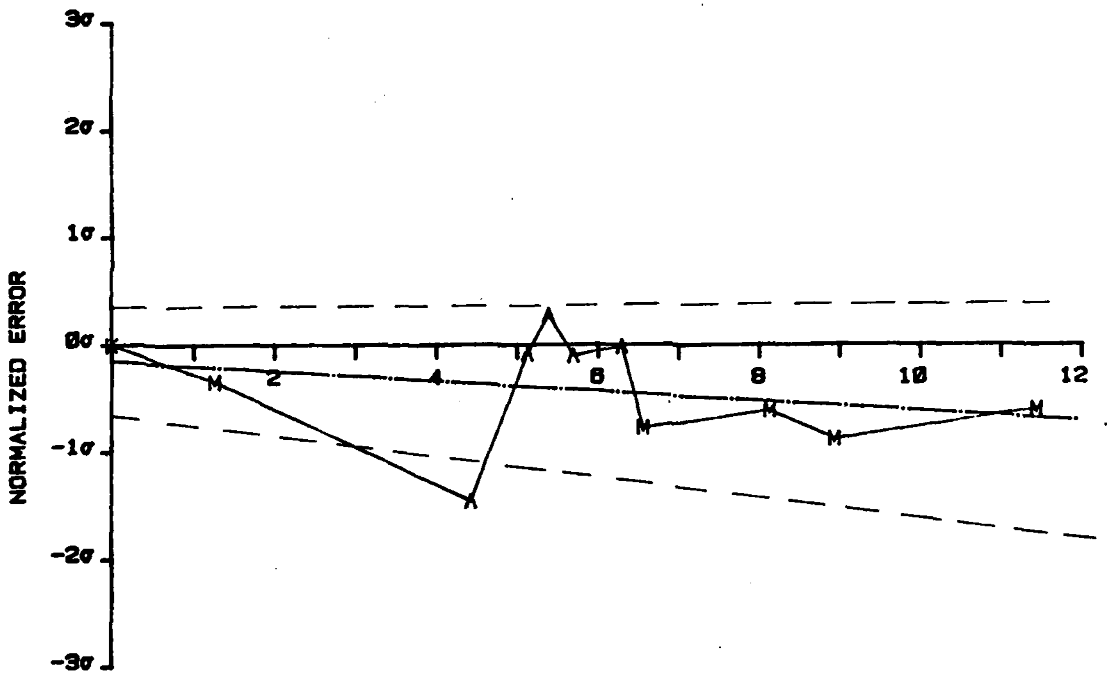


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.110
4.430	.690
5.130	.160
5.400	.330
5.700	.032
6.300	.150
6.560	-.230
8.130	-.040
8.930	-.150
11.430	.120

Figure A-25. KSZHE.

IMU S/N 5
KOXE
1 σ = 100 ug

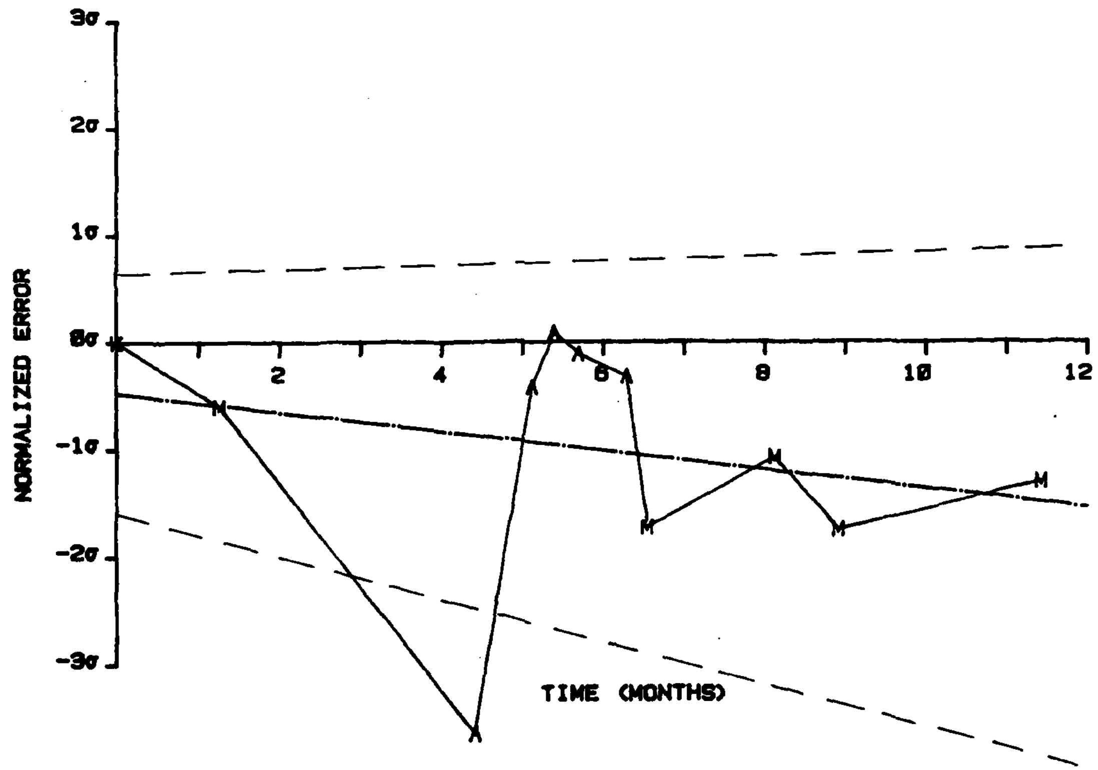


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.340
4.430	-1.450
5.130	-.080
5.400	.280
5.700	-.098
6.300	-.014
6.560	-.770
8.130	-.610
8.930	-.880
11.430	-.600

Figure A-26. KOXE.

IMU S/N 5
KSXE
1 σ = 50 ug/g

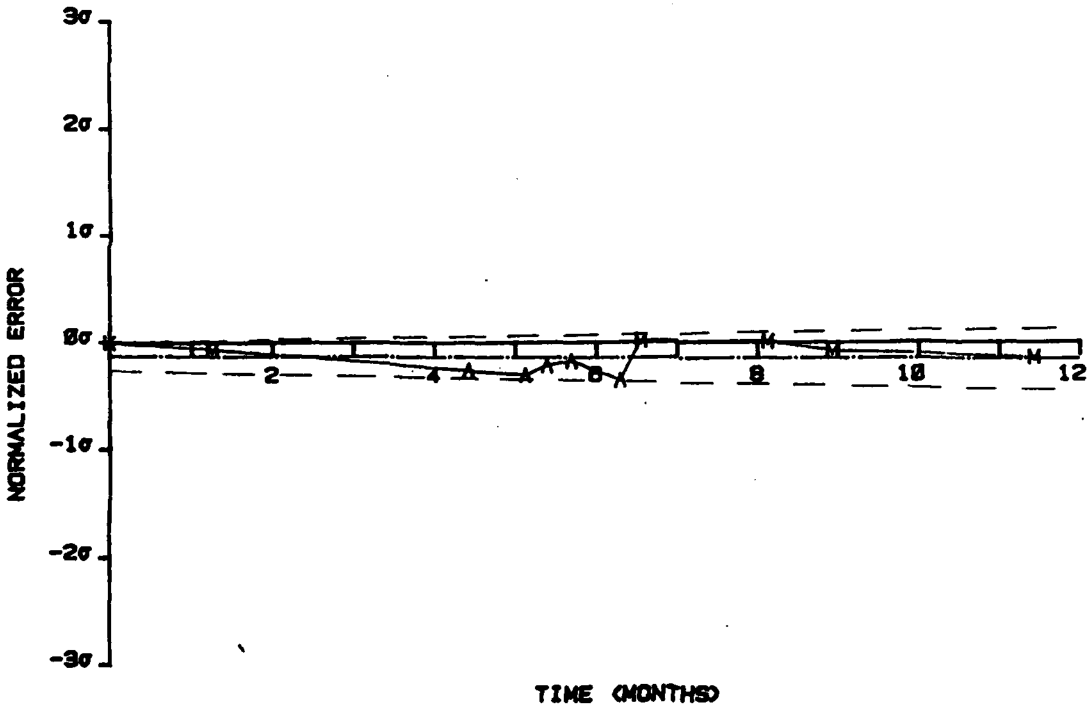


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.600
4.430	-3.640
5.130	-.420
5.400	.090
5.700	-.110
6.300	-.320
6.560	-1.720
8.130	-1.070
8.930	-1.750
11.430	-1.300

Figure A-27. KSXE.

IMU S/N 5
KOXHE
1 σ = 100 ug

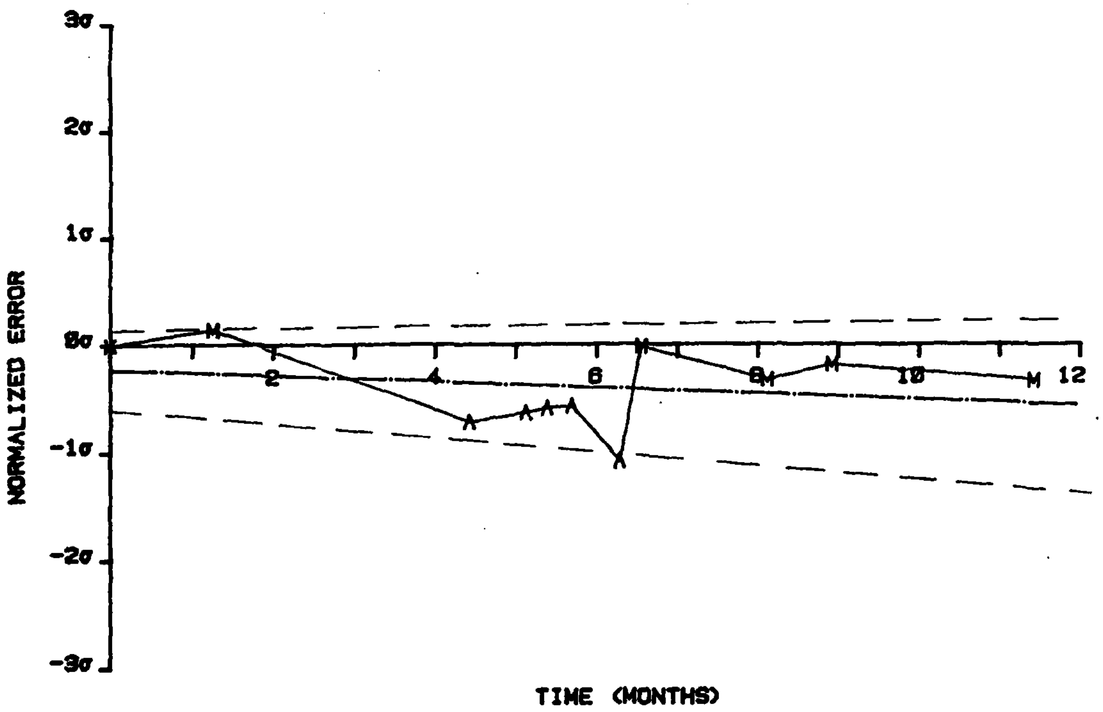


CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.060
4.430	-.260
5.130	-.300
5.400	-.210
5.700	-.170
6.300	-.350
6.560	.020
8.130	.010
8.930	-.080
11.430	-.140

Figure A-28. KOXHE.

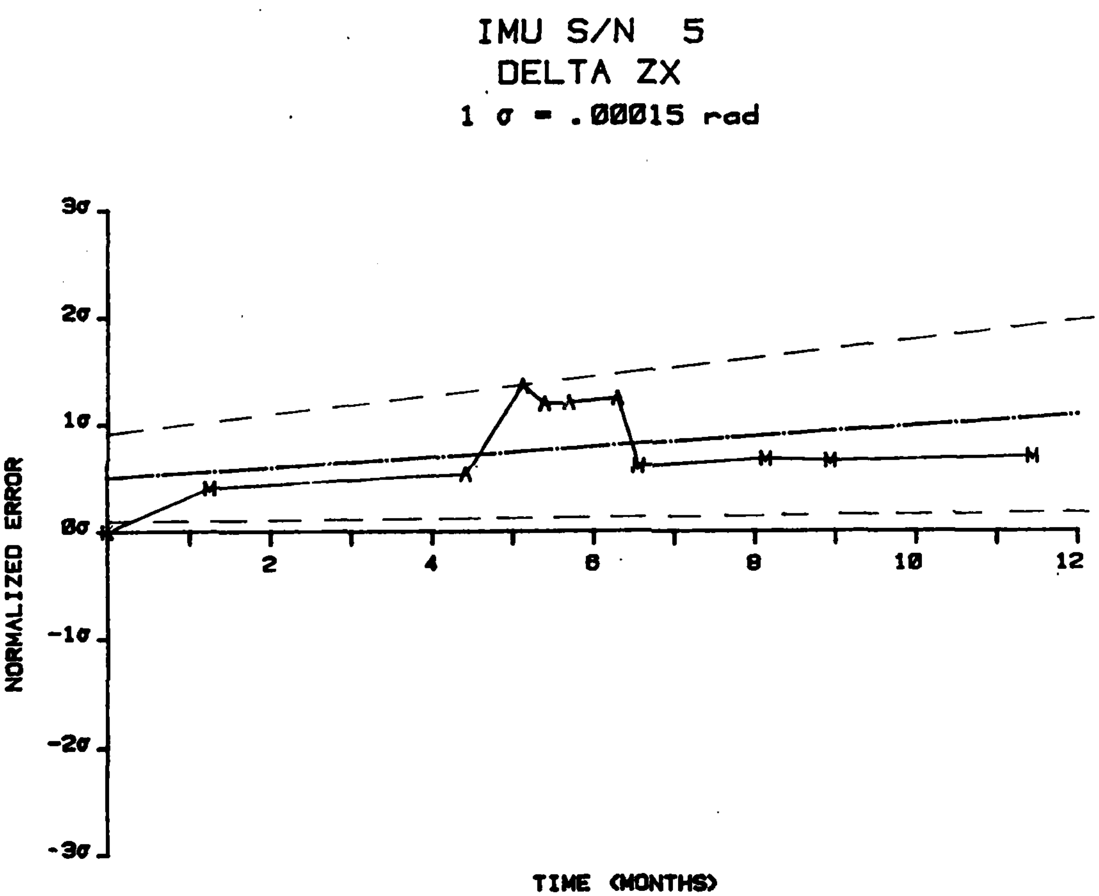
IMU S/N 5
KSXHE
1 σ = 50ug/g



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.140
4.430	-.720
5.130	-.630
5.400	-.590
5.700	-.570
6.300	-1.060
6.560	-.020
8.130	-.330
8.930	-.190
11.430	-.340

Figure A-29. KSXHE.



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	.410
4.430	.540
5.130	1.360
5.400	1.190
5.700	1.200
6.300	1.240
6.560	.610
8.130	.680
8.930	.660
11.430	.700

Figure A-30. DELTA ZX.

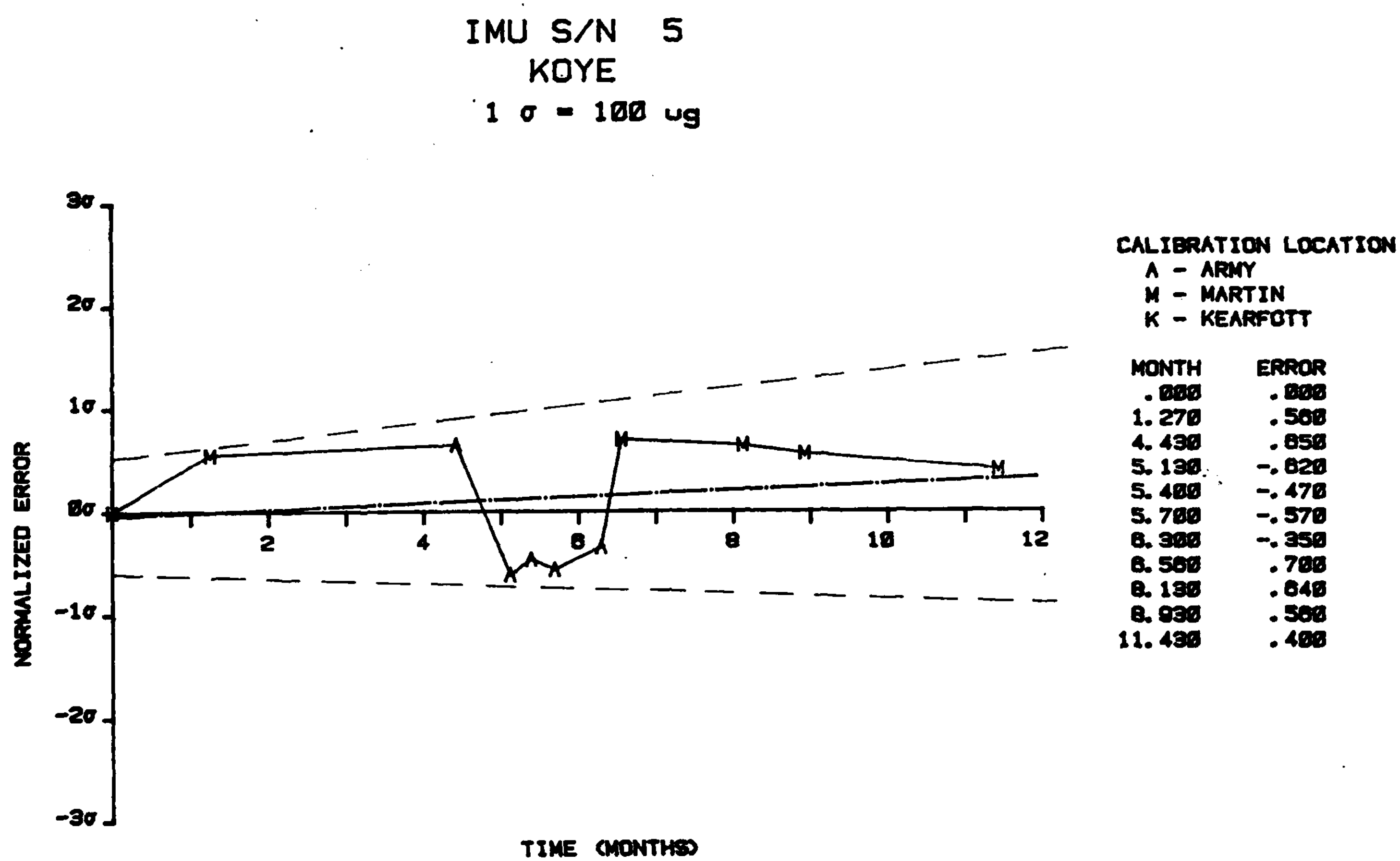


Figure A-31. KOYE.

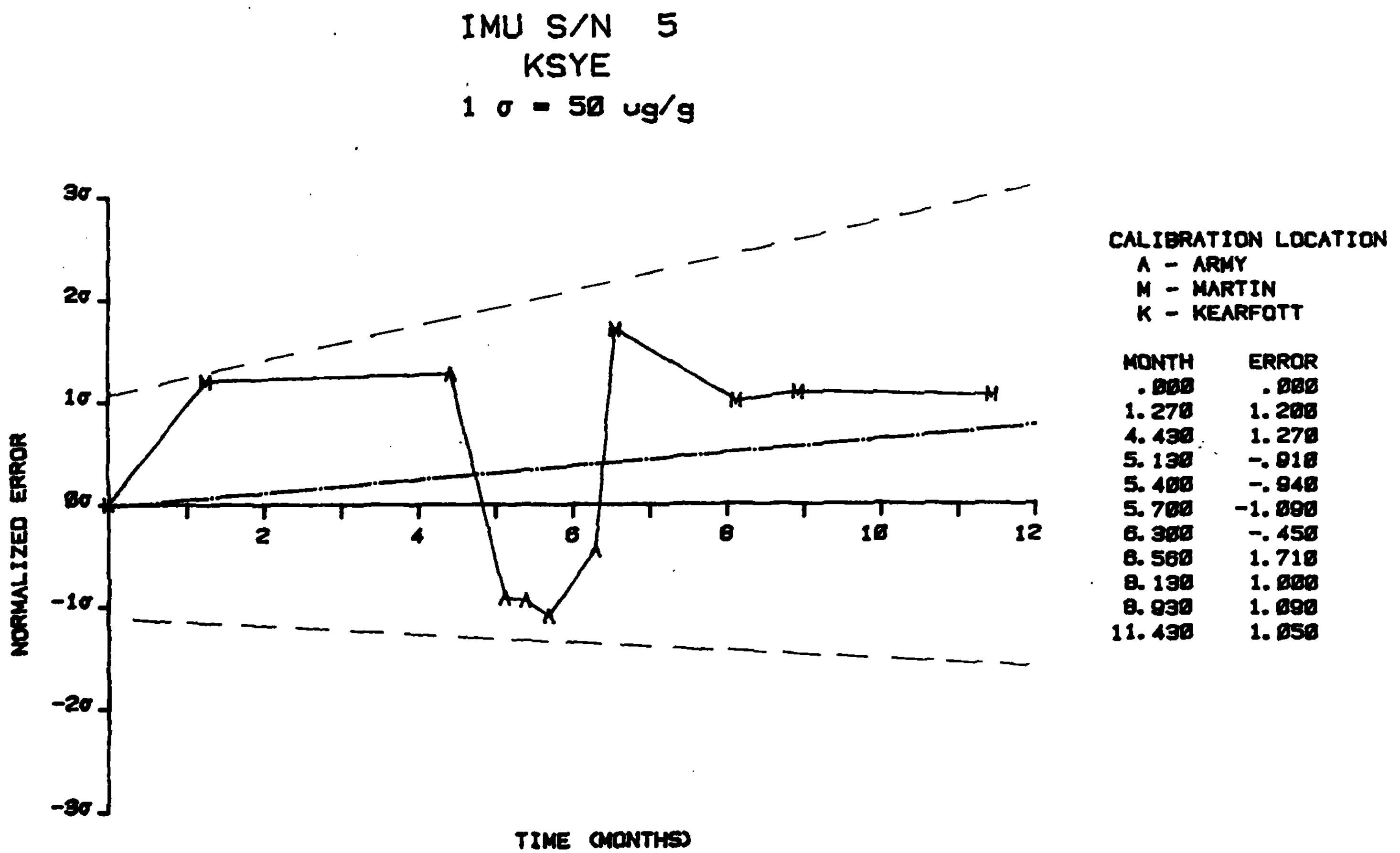
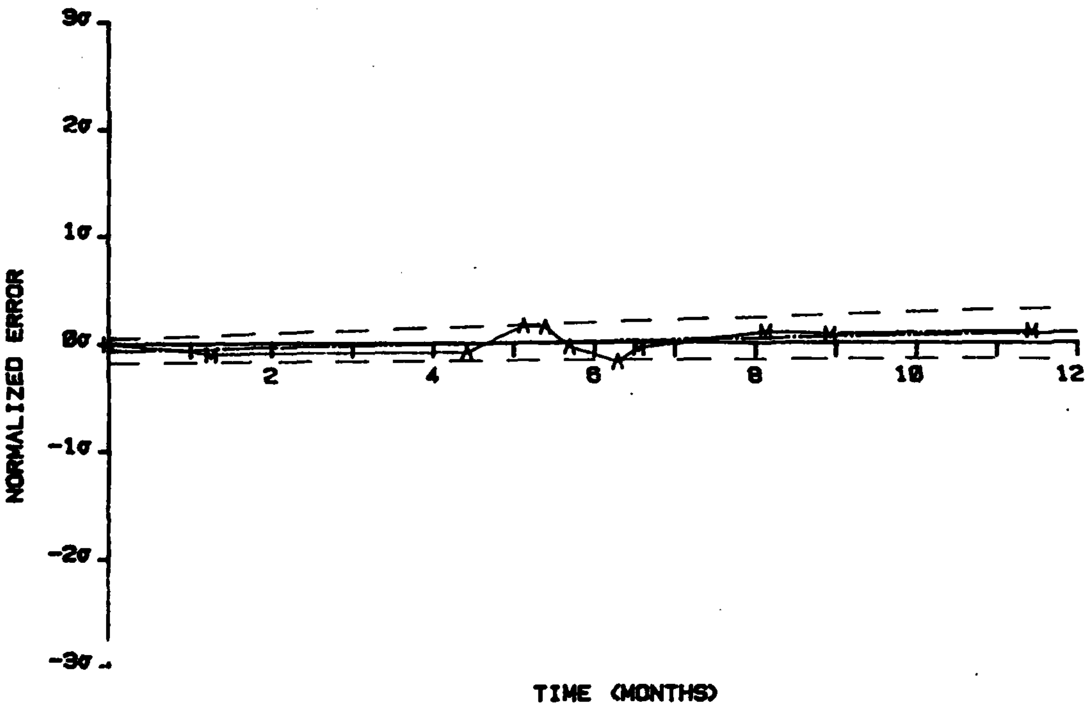


Figure A-32. KSYE.

IMU S/N 5
KOYHE
$1\ \sigma = 100\ \mu g$



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.100
4.430	-.090
5.130	.160
5.400	.150
5.700	-.040
6.300	-.180
6.560	-.050
8.130	.100
8.930	.080
11.430	.110

Figure A-33. KOYHE.

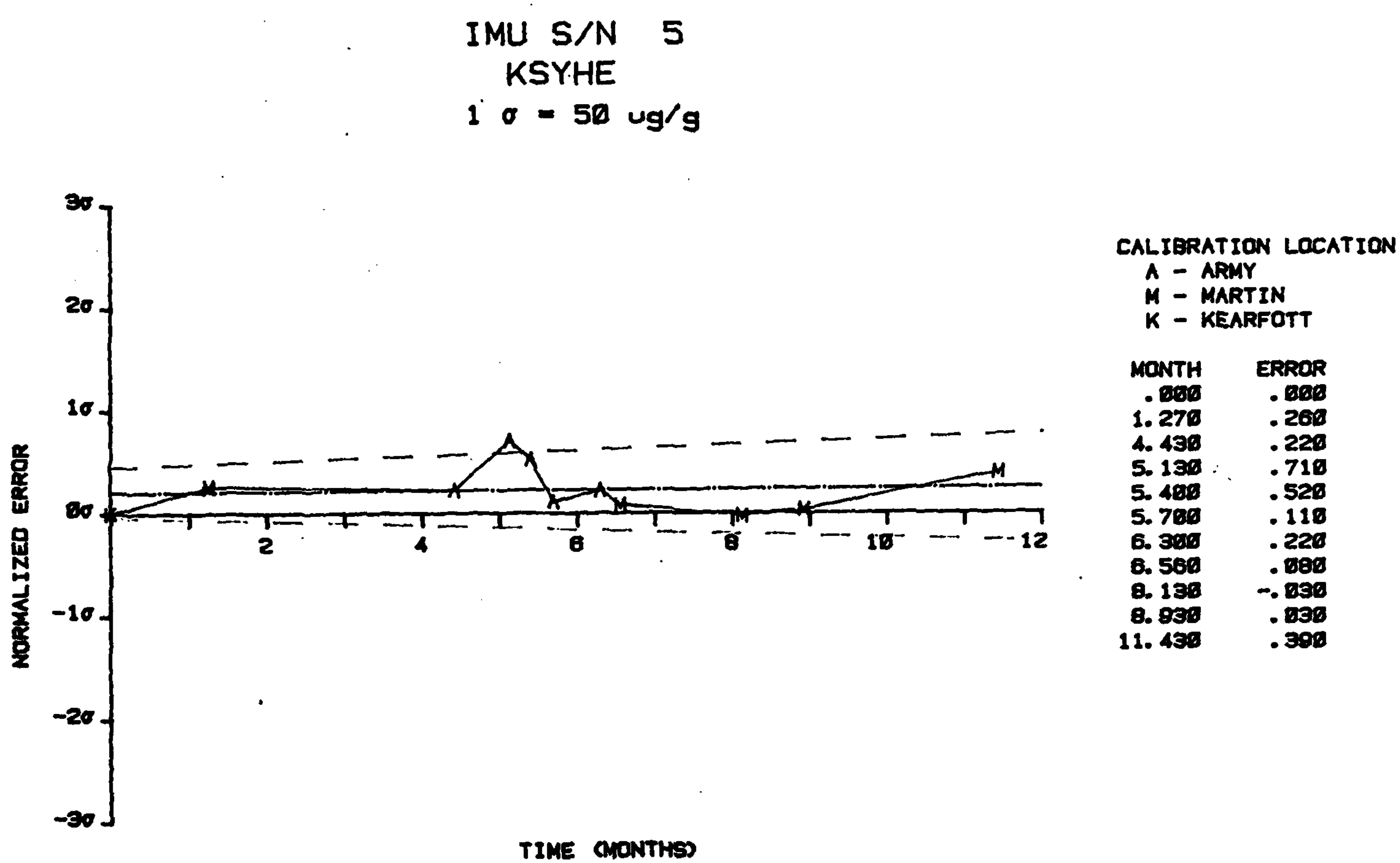


Figure A-34. KSYHE.

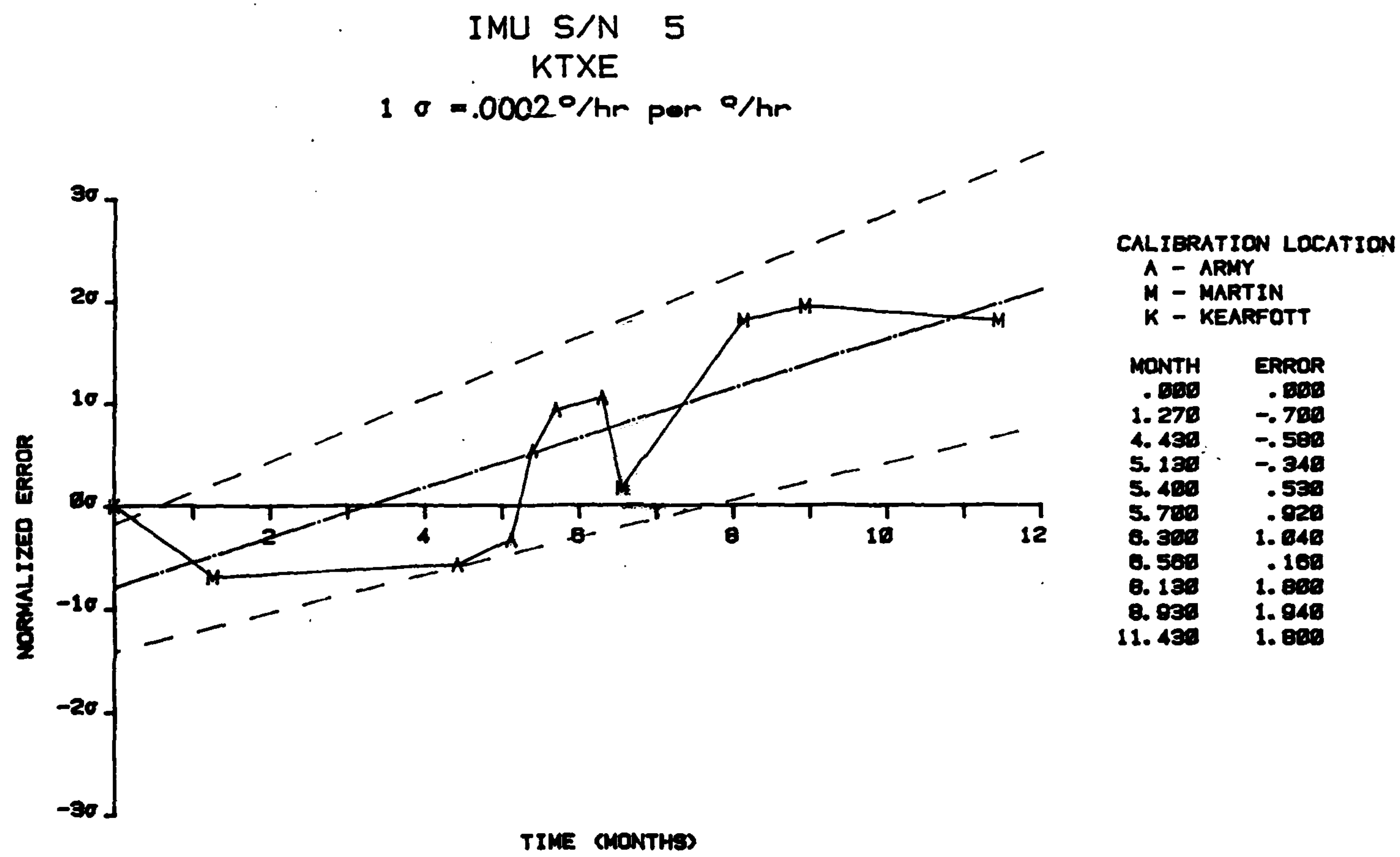
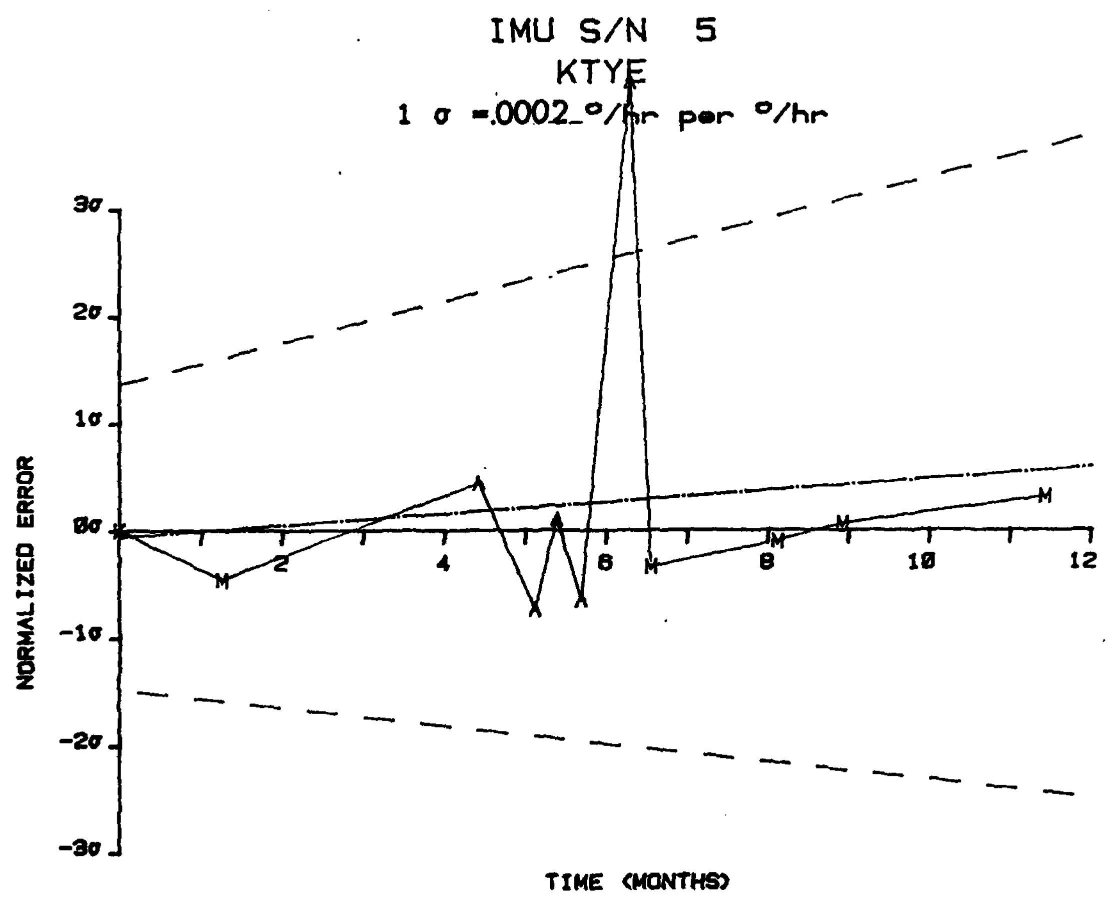


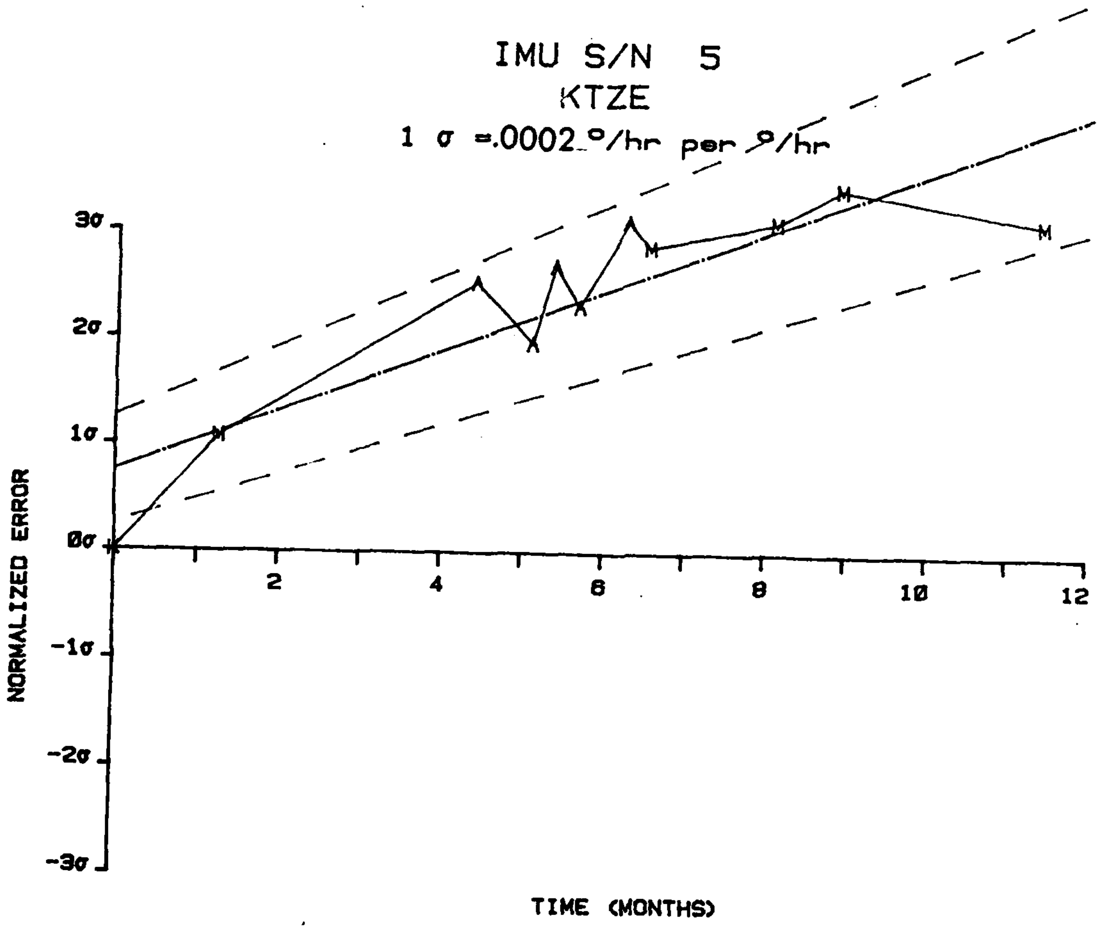
Figure A-35. KTXE.



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	-.460
4.430	.440
5.130	-.740
5.400	.100
5.700	-.650
6.300	4.190
6.580	-.340
8.130	-.105
8.930	.060
11.430	.310

Figure A-36. KTYE.



CALIBRATION LOCATION
A - ARMY
M - MARTIN
K - KEARFOTT

MONTH	ERROR
.000	.000
1.270	1.070
4.430	2.520
5.130	1.950
5.400	2.680
5.700	2.300
6.300	3.100
6.560	2.860
8.130	3.100
8.930	3.420
11.430	3.100

Figure A-37. KTZE.

TABLE A-1. IMU S/N 001 STATISTICS

IMU SERIAL NUMBER 001
NCAL = 27

PARAM.	INTERCEPT A	SLOPE B	STD ERROR SYX	CORR COEFF R	STD ERROR SB	RMS ERROR Y RMS	AVG Y AVG	ERROR STD DEV SY	X_2	X_1
CFZE	.187	-.044	1.006	.175	.050	.983	-.028	1.002	72.165	23.223
DSZE	-.347	-.027	.707	.152	.035	.839	-.480	.701	98.340	31.592
DIZE	8.230	-1.815	14.523	.451	.719	15.669	-.698	15.952	6.187	-1.299
KIYE	-[illegible]7	-.077	.401	.613	.020	.704	-.506	.498	37.250	25.400
KIYHE	-.224	-.032	.379	.320	.019	.541	-.380	.372	87.518	47.480
KIXE	-.277	-.056	.457	.446	.023	.740	-.554	.500	48.351	28.703
KIXHE	-.462	-.012	.334	.148	.017	.615	-.523	.331	204.853	76.133
DOZE	-.854	.126	.835	.520	.041	.970	-.234	.959	30.575	18.032
DFXE	1.315	.112	1.321	.323	.065	2.298	1.864	1.369	15.089	2.052
KIZE	-.175	.055	.502	.405	.025	.537	.096	.539	57.592	33.401
KIZHE	.798	-.015	.554	.108	.027	.901	.724	.546	253.745	76.537
DFYE	.915	-.026	.673	.155	.033	1.024	.787	.669	149.588	54.452
DSXE	-.454	.125	.960	.465	.048	1.056	.160	1.064	27.665	14.462
DSYE	.454	-.125	.960	.465	.048	1.056	-.160	1.064	27.665	14.462
DIXE	.173	.262	2.167	.439	.107	2.742	1.462	2.364	10.788	1.789
DIYE	.173	.262	2.167	.439	.107	2.742	1.462	2.364	10.788	1.789
DELTA YX	.703	-.063	.340	.577	.017	.567	.393	.417	58.720	42.072
DELTA ZY	-.091	.009	.051	.595	.003	.076	-.045	.063	327.864	253.776
KOZE	-.243	-.003	.156	.073	.008	.299	-.258	.153	916.608	242.249
KSZE	-1.946	.097	.832	.426	.041	1.715	-1.469	.901	50.997	29.777
KOZHE	-.130	-.009	.148	.236	.007	.233	-.182	.150	320.460	166.783
KSZHE	-1.529	.070	.913	.297	.045	1.498	-1.182	.938	64.287	31.256
KOXE	.417	-.005	.391	.048	.019	.546	.374	.384	731.622	125.798
KSXE	.713	.002	.719	.013	.036	1.002	.724	.705	1022.656	41.306
KOXHE	-.307	.019	.263	.279	.013	.339	-.214	.268	174.802	95.356
KSXHE	-.807	.036	.601	.235	.030	.867	-.630	.607	105.936	48.772
DELTA ZX	-.324	.023	.211	.396	.010	.307	-.214	.225	147.616	94.424
KOYE	-.572	.044	.483	.343	.024	.610	-.356	.505	81.619	45.609
KSYE	-1.221	.124	.743	.463	.047	1.175	-.612	1.047	34.090	17.218
KOYHE	.170	-.057	.557	.380	.028	.589	-.109	.590	55.925	31.017
KSYHE	.437	-.143	1.455	.369	.072	1.530	-.266	1.536	23.996	7.208
KTXE	-.682	-.179	.952	.560	.058	1.797	-1.422	1.122	12.930	5.760
KTYE	-.835	-.086	1.281	.235	.078	1.735	-1.173	1.288	25.035	5.369
KTZE	.065	.024	.442	.189	.027	.460	.163	.440	123.907	49.259

TABLE A-2. IMU S/N 002 STATISTICS

IMU SERIAL NUMBER 002
NCAL = 19

PARAM.	INTERCEPT A	SLOPE B	STD ERROR SYX	CORR COEFF P	STD ERROR SB	RMS ERROR Y RMS	AVG Y AVG	ERROR STD DEV SY	X_2	X_1
DFZE	.312	-.220	.732	.555	.082	.891	-.326	.853	15.080	8.545
DSZE	.020	-.036	.201	.356	.023	.220	-.084	.209	84.853	48.407
DIZE	.835	-.094	.654	.296	.073	.856	.560	.665	40.861	19.011
KIYE	-.126	-.267	.208	.941	.023	1.077	-.907	.596	10.760	9.177
KIYHE	-.211	-.194	.203	.900	.023	.896	-.780	.453	14.347	11.901
KIXE	.040	-.123	.125	.906	.014	.424	-.321	.286	24.645	21.226
KIXHE	-.276	-.191	.218	.884	.025	.945	-.835	.454	14.239	11.608
DOZE	-.115	.073	.384	.380	.043	.405	.099	.403	42.569	23.479
DFXE	.365	-.040	.296	.280	.033	.383	.247	.300	83.892	41.789
KIZE	3.049	-1.957	6.060	.572	.681	7.481	-2.674	7.178	3.091	-.004
KIZHE	-.207	.047	.289	.333	.032	.298	-.069	.298	67.900	36.610
DFYE	-.050	-.004	.214	.044	.024	.212	-.063	.208	678.353	96.306
DSXE	-.119	-.050	.192	.493	.022	.330	-.266	.214	57.311	37.459
DSYE	.119	.050	.192	.493	.022	.338	.266	.214	57.311	37.459
DIXE	-.324	.394	1.053	.628	.118	1.524	.827	1.315	8.444	4.435
DIYE	-.324	.394	1.053	.628	.118	1.524	.827	1.315	8.444	4.435
DELTA YX	.151	-.066	.289	.444	.033	.309	-.044	.314	47.423	28.912
DELTA ZY	-.126	.003	.214	.028	.024	.234	-.118	.208	1123.373	108.471
KOZE	-.016	.033	.069	.714	.008	.123	.080	.076	92.520	73.052
KSZE	-.246	-.084	.501	.340	.056	.704	-.491	.517	32.865	16.083
KOZHE	.036	.028	.065	.681	.007	.146	.119	.087	105.124	81.552
KSZHE	.161	-.069	.328	.415	.037	.343	-.041	.350	45.644	26.707
KOXE	.349	-.195	.364	.756	.041	.570	-.220	.540	17.205	12.675
KSXE	.140	-.098	1.272	.165	.143	1.229	-.148	1.253	31.906	7.738
KOXHE	.078	-.153	.267	.778	.030	.546	-.370	.413	20.075	15.346
KSXHE	.148	-.315	.544	.781	.061	1.129	-.773	.846	9.997	6.925
DELTA ZX	.083	-.050	.136	.622	.015	.176	-.063	.168	61.669	45.175
KOYE	-.130	.140	.330	.674	.037	.507	.279	.435	22.397	15.828
KSYE	-.412	.193	.761	.480	.086	.835	.152	.843	17.688	7.520
KOYHE	.059	.193	.320	.793	.036	.796	.622	.510	15.261	11.466
KSYHE	-.267	.274	.648	.675	.073	.987	.535	.853	11.911	7.547
KTXE	-.217	.030	.767	.087	.086	.737	-.129	.747	107.041	21.066
KTYE	.255	.063	.776	.173	.089	.880	.440	.784	43.589	12.787
KTZE	.037	.088	.370	.469	.042	.494	.297	.407	33.518	19.933

TABLE A-3. IMU S/N 003 STATISTICS

IMU SERIAL NUMBER 003
NCAL = 10

PARAM.	INTERCEPT A	SLOPE B	STD ERROR SYX	CORR COEFF R	STD ERROR SB	RMS ERROR Y RMS	AVG Y AVG	ERROR STD DEV SY	X_2	X_1
DFZE	.194	.135	.425	.600	.064	.758	.591	.501	20.723	11.948
DSZE	.081	-.027	.200	.302	.030	.180	.002	.178	114.440	50.530
DIZE	-.333	.314	.494	.831	.074	.989	.588	.838	10.617	7.314
KIYE	-.283	-.111	.617	.390	.093	.854	-.608	.632	24.479	10.318
KIYHE	-.102	-.115	.505	.472	.076	.675	-.439	.541	25.206	12.537
KIXE	-.262	-.135	.669	.430	.100	.934	-.658	.699	20.249	8.777
KIXHE	-.109	-.153	.638	.492	.096	.915	-.638	.691	18.346	8.728
DOZE	-.185	.021	.336	.147	.050	.327	-.122	.320	149.712	37.754
DFXE	-.390	-.766	2.038	.663	.306	3.596	-2.646	2.567	3.395	.525
KIZE	.056	-.077	.302	.513	.045	.357	-.169	.331	39.924	22.609
KIZHE	-.007	-.028	.144	.415	.022	.168	-.089	.149	107.021	57.412
DFYE	-.414	.086	1.331	.151	.200	1.215	-.161	1.270	39.500	7.275
DSXE	.124	-.347	.861	.689	.129	1.388	-.894	1.119	9.000	4.752
DSYE	-.124	.347	.861	.689	.129	1.388	.894	1.119	9.000	4.752
DIXE	-.845	-.171	.573	.575	.086	1.485	-1.346	.660	12.612	6.156
DIYE	-.845	-.171	.573	.575	.086	1.485	-1.346	.660	12.612	6.156
DELTA YX	.468	-.079	.358	.460	.054	.431	.237	.380	44.012	23.467
DELTA ZY	.007	.003	.016	.387	.002	.023	.017	.016	1050.858	566.989
KOZE	-.056	.042	.565	.172	.085	.517	.067	.541	72.775	19.644
KSZE	-.195	.005	.701	.018	.105	.653	-.180	.661	612.038	22.570
KOZHE	-.081	.005	.068	.170	.010	.091	-.066	.065	618.003	198.033
KSZHE	-.319	.211	.493	.709	.074	.693	.299	.659	15.758	9.930
KOXE	-.395	-.070	.389	.392	.058	.710	-.601	.399	37.029	17.215
KSXE	-.464	-.180	.856	.445	.128	1.311	-.993	.901	14.052	5.438
KOXHE	.018	-.005	.104	.105	.016	.093	.004	.098	646.112	143.723
KSXHE	.260	-.015	.301	.120	.045	.351	.223	.286	211.683	43.916
DELTA ZX	.067	-.148	.689	.452	.103	.782	-.367	.720	20.715	9.457
KOYE	.179	.051	.360	.316	.054	.472	.323	.350	55.508	23.470
KSYE	.437	.050	.764	.153	.115	.905	.584	.729	51.097	10.907
KOYHE	.055	.005	.143	.081	.021	.146	.070	.135	596.433	106.189
KSYHE	.014	.020	.240	.191	.036	.230	.072	.230	150.848	49.206
KTXE	.075	-.334	.428	.835	.066	1.171	-.846	.860	9.218	6.618
KTYE	.227	-.355	.347	.928	.054	1.114	-.751	.872	9.097	7.050
KTZE	-.122	.013	.256	.120	.040	.244	-.087	.242	245.041	54.614

TABLE A-4. IMU S/N 005 STATISTICS

IMU SERIAL NUMBER 005
NCAL = 11

PARAM.	INTERCEPT A	SLOPE B	STD ERROR SYX	CORR COEFF R	STD ERROR SB	RMS ERROR Y RMS	AVG Y AVG	ERROR STD DEV SY	X_2	X_1
DFZE	-.426	.111	.523	.585	.051	.620	.211	.612	30.749	17.931
DSZE	.847	.115	.552	.578	.054	1.628	1.508	.642	18.738	9.473
DIZE	1.336	-.555	2.109	.668	.206	3.164	-1.858	2.687	7.311	2.925
KIYE	.052	-.166	.259	.910	.025	1.066	-.905	.591	18.349	14.575
KIYHE	.087	-.267	.376	.925	.037	1.715	-1.462	.940	11.468	8.857
KIXE	.136	-.161	.313	.868	.031	.975	-.790	.599	19.484	14.733
KIXHE	-.960	.083	1.234	.223	.121	1.243	-.484	1.201	47.826	13.387
DOZE	-.804	.100	.709	.431	.069	.748	-.231	.746	38.215	10.315
DFXE	-.156	-.042	.280	.452	.027	.487	-.396	.298	68.345	37.162
KIZE	.621	-.059	.676	.285	.066	.697	.281	.669	61.242	23.586
KIZHE	.557	-.090	.499	.524	.049	.532	.037	.556	37.415	21.981
DFYE	-.531	.188	.413	.840	.040	.881	.549	.722	10.811	13.663
DSXE	-.166	-.008	.276	.078	.027	.328	-.212	.263	356.212	73.223
DSYE	.166	.008	.276	.098	.027	.328	.212	.263	356.212	73.223
DIXE	-.917	-.042	2.214	.064	.217	2.317	-1.158	2.105	47.752	-.508
DIYE	-.917	.042	2.214	.064	.217	2.317	-1.150	2.105	49.752	.508
DELTA YX	.408	.006	.475	.043	.046	.617	.443	.451	428.773	40.298
DELTA ZY	-.055	.016	.067	.630	.007	.086	.037	.081	192.362	133.327
KOZE	-.097	-.024	.202	.372	.020	.308	-.236	.207	121.717	61.816
KSZE	-.652	.069	.946	.241	.093	.918	-.255	.925	52.875	16.730
KOZHE	-.010	-.038	.051	.731	.005	.261	-.229	.132	78.561	63.287
KSZHE	.196	-.015	.256	.202	.025	.259	.107	.248	206.220	72.583
KOXE	-.146	-.047	.505	.301	.047	.633	-.415	.502	61.012	24.433
KSXE	-.472	-.089	1.118	.262	.109	1.439	-.905	1.099	28.344	7.096
KOXHE	-.122	-.003	.136	.076	.013	.187	-.140	.129	944.329	167.533
KSXHE	-.230	-.028	.372	.252	.036	.525	-.394	.365	97.343	36.959
DELTA ZX	.507	.048	.411	.368	.040	.877	.781	.419	52.298	23.702
KOYE	-.038	.030	.564	.180	.055	.536	.136	.544	100.435	28.953
KSYE	-.019	.065	1.081	.202	.106	1.060	.357	1.047	46.127	11.317
KOYHE	-.064	.013	.111	.379	.011	.109	.013	.114	229.372	121.939
KSYHE	.210	.003	.244	.045	.024	.318	.228	.232	868.765	93.837
KTXE	-.794	.242	.614	.802	.060	1.105	.597	.974	15.689	10.533
KTYE	-.057	.054	1.420	.127	.139	1.320	.255	1.358	56.381	8.473
KTZE	.751	.282	.500	.887	.049	2.567	2.373	1.027	7.978	5.286

TABLE A-5. PREDICTED INTERVAL BETWEEN CALIBRATIONS, X_1 (MONTHS)

IMU S/N	DFZE	DSZE	DIZE	KIYE	KIYHE	KIXE	KIXHE	DOZE	DFXE	KIZE	KIZHE	DFYE	DSXE	DSYE	DIXE	DIYE	DELYX	DELZY	KOZE	KSZE
001	23.2	31.4		25.5	47.5	28.7	76.1	18.0	2.0	33.4	76.5	54.4	14.5	14.5	1.8	1.8	42.1	253.8	242.2	29.8
002	8.5	48.4	19.0	9.2	11.9	21.2	11.6	23.5	41.8		36.6	96.3	37.4	37.4	4.4	4.4	28.9	108.5	73.0	16.1
003	11.9	50.5	7.3	10.3	12.5	8.8	8.7	39.8	.5	22.6	57.4	7.3	4.8	4.8	6.2	6.2	23.5	567.0	19.6	22.6
004																				
005	17.9	9.5	2.9	14.6	8.8	14.7	13.4	18.3	37.2	23.5	22.0	13.7	73.2	73.2		1	40.3	133.4	61.8	16.7
006																				
007																				
008																				
009																				
010																				
011																				
012																				
013																				
AVG	15.4	38.6	7.3	14.9	20.2	18.4	27.4	24.9	20.3	19.9	48.1	42.9	32.5	32.5	3.1	3.1	33.7	265.7	99.2	21.3

TABLE A-5. (Concluded)

IMU S/N	KOZHE	KSZHE	KOXE	KSXE	KOXHE	KSXHE	DELZX	KOYE	KSYE	KOYHE	KSYHE	KTXE	KTYE	KTZE
001	166.8	31.2	125.8	41.4	95.4	48.8	94.4	45.6	19.2	31.0	9.2	5.8	5.4	49.2
002	81.6	26.7	12.7	7.7	15.3	6.9	45.2	15.8	9.5	11.5	7.5	21.1	12.8	19.9
003	198.0	9.9	17.2	5.4	143.9	48.9	9.4	23.5	10.9	106.2	49.2	6.6	7.0	54.6
004														
005	68.3	72.6	24.4	7.1	167.5	37.0	23.7	29.0	11.3	121.9	93.8	10.5	8.5	5.3
006														
007														
008														
009														
010														
011														
012														
013														
AVG	128.7	35.1	45.0	15.4	105.5	35.4	43.2	28.5	12.7	67.6	39.9	11.0	8.4	32.2

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